

RF Project 4207
Final Report

**the
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research foundation

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THE IDENTIFICATION OF SCIENTIFIC
PROGRAMS TO UTILIZE THE SPACE ENVIRONMENT

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June 1975 - June 1976

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION
LDEF Project Office
Langley Research Center
Hampton, Virginia 23365

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Programs to Utilize the Space Environment

by

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Summary

A program to identify and develop ideas for scientific experimentation on the Long Duration Exposure Facility has been conducted at The Ohio State University. The objectives of the program were three-fold:

1. To encourage as large a number of faculty as possible to consider the potential for contributions in their fields by conducting long duration experiments in space.
2. To provide an effective mechanism for proposal development such that well defined research plans can be submitted to the LDEF program.
3. To encourage as large a number of University faculty in as wide a range of disciplines as possible to examine societal and scientific benefits of LDEF and Spacelab.

These objectives were achieved via solicitation of research prospectuses from the faculty in disciplines relevant to the scientific capabilities of LDEF and the award of several small grants on a competitive basis for development of some of the prospectuses into detailed research proposals.

Four research proposals were developed in the OSU/LDEF Program. Each of these was judged to have sufficient specificity in its objectives and experimental design, the potential for making a significant contribution to scientific knowledge, and a high probability of success if implemented on LDEF. The topics and objectives of these proposals are,

1. Ultra Pure Germanium Gamma Ray Radiation Detectors in the Space Environment

Objective: To develop and demonstrate an x-ray and γ -ray spectroscopy system incorporating a temperature cyclable high-purity germanium detector and diode heat pipe cryogenic system for cooling. The development of high-purity germanium detector technology with heat pipe cooling will broaden the potential of gaining new insight into the universe through high energy photon characterization such as solar flares phenomena, stellar evolution, and nuclear astrophysics. Such detectors can be fabricated into complex geometrical configurations such as required in telescopes and still maintain excellent energy resolving properties.

2. Growth, Morphogenesis and Metabolism of Plant Embryos in the Zero-Gravity Environment

Objective: To devise a candidate experiment using a system from flowering plants that would be suitable to be carried in

space on long duration flights. The effect of the space environment on the growth and development of embryos will be monitored by fixing samples at timed intervals and analyzing them for rate of cell division, cell expansion and differentiation of tissues and organs. Comparison of RNA and protein contents of whole cells and subcellular fractions of cells of embryos grown on earth and in space will be made to determine the effect of zero gravity on macromolecule synthesis during embryogenesis. The data from the proposed experiments will provide meaningful information on embryonic plant growth in the gravity free environment of space. If the space environment induces mutations in the embryogenic cells, mutants of commercial significance with desirable attributes may be obtained.

3. Effect of Zero Gravity on the Growth and Pathogenicity of Selected Zoopathic Fungi

Objective: To compare growth rates, pathogenicities in laboratory animals, and ultrastructure between cells exposed to zero gravity and solar radiation and earthbound cells of a comparable age-in-culture without transfer. The investigations will include Candida Albicans and Trichophyton Metagrophytes, both of which are common inducers of diseased states in humans. The results of the comparisons of the two environments on both organisms could be important for future manned flights. Candida Albicans, a yeast, is a common commensal in the oral cavity in about 35% of the human population, while about 85% of normal, healthy individuals have C. albicans positive stool specimens. Virtually any internal or external stress that alters the immunologic responsiveness of the human host allows the fungus to evoke overt localized or generalized candidiasis. Trichophyton mentagrophytes is one of the two most common causes of tinea pedis. It is possible that new kinds of treatment for candidiasis, and trichophytosis could eventuate from the results of the proposed studies.

4. Importance of Gravity to Survival Strategies of Small Animals

Objective: To make descriptive and quantitative comparisons of structure, physiology, population densities, and subsequent behavior of earthbound and orbiting colonies of small (< 0.0001 gm) animals. Since terrestrial resources are distributed along a gravitational gradient and small animals use the gravitational field for orientation, the proposed study will lead to understanding of the importance of gravity to these populations. Gravitational effects may be direct or mediate the selection of genetic variants that are preadapted to weightlessness. The results of the study will also be important to the planning of self-contained ecosystems designed for support of commercial or public exploitation of space in

the vicinity of the earth or extended travel in outer space. These gravitational influences must be identified and described before an estimate of their benefits on earth can be made.

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I. INTRODUCTION

A. Overview of STS/LDEF Scientific Programs

The development of the Space Transportation System and its orbiting Spacelab and Long Duration Exposure Facility (LDEF) programs will provide the means by which space will become a practical and commonplace laboratory for experimental research. The Space Transportation System (STS), which will become operational in 1979, will provide a large number of flight opportunities, carry large payloads, and will be capable of retrieval of objects in space for return to earth. These capabilities will make possible a wide range of scientific and technologically directed experiments to an expanded number of researchers, at relatively low cost, and with a high probability of success since data will be analyzed either on earth (LDEF Program) or monitored by a researcher on-board the vehicle (Spacelab program). The sustained low gravity conditions of space which will be maintained in these experiments will provide a unique opportunity to explore new physical phenomena and to test low gravity effects on well known phenomena where no such tests are possible on earth.

The benefits to society from the increased capabilities in scientific experimentation afforded by the STS will be derived in areas such as: 1) communications, 2) earth resources surveys, 3) manufacturing in space, 4) development of manufacturing technologies for space, 5) national defense, 6) navigation, 7) scientific and technical knowledge, and 8) weather observation and prediction. Each of these areas has great potential for scientific development from both the basic knowledge and hardware utility viewpoints. The scientific programs possible with the STS will form the basis for this development within the unique environment of space.

The LDEF is the first vehicle to be flown on the STS, and the objective of programs built upon its capabilities is largely scientific in nature. Early LDEF missions will:

1. Demonstrate its utility as an orbiting research laboratory for a wide variety of scientific experiments in many disciplinary areas.
2. Obtain new scientific information within the space environment via essentially passive experiments.

To provide a broad base of possible scientific experiments and potential contractors in the university community for LDEF programs, NASA initiated a programmatic effort early in FY '76 to provide support to university faculty members for development of preliminary and detailed research proposals. The Ohio State University was selected as a participant in this program, and the funds provided to the University were used to cover faculty and/or graduate students salaries and other incidental costs necessary in the development of research ideas

into proposal form. This report describes the OSU program structure and presents all of the proposals developed for the LDEF Program.

B. Capability of the Ohio State University to Contribute to STS Scientific Programs

The Ohio State University is singularly and ideally qualified to participate in STS research programs. It has a wide spectrum of scientific and technological disciplines represented on its faculty. It is a national leader in graduate education and research in the sciences and engineering, with the capability and experience to contribute in all of the areas mentioned above.

The University, with the nation's largest single campus enrollment of 49,000, is the center of graduate education and research in Ohio and a major national graduate research institution. The University faculty comprises 2,500 full time professors and 1,100 additional instructional personnel. For 1970-1971, the latest period for which figures are available, the University ranked seventh nationally in the number of Ph.D.'s granted.

The fields of study for M.Sc. and Ph.D. Degrees within the University which have relevance to STS research programs are:

Aeronautical and Astronautical Engineering	Geography
Astronomy	Geology and Minerology
Biochemistry	Mechanical Engineering
Biophysics	Medical Microbiology
Botany	Medicine
Ceramic Engineering	Metallurgical Engineering
Chemical Engineering	Microbiology
Chemistry	Nuclear Engineering
Civil Engineering	Pharmacology
Computer and Information Science	Pharmacy
Electrical Engineering	Physics
Engineering Mechanics	Physiological Chemistry
Entomology	Physiology
Environmental Biology	Plant Pathology
Genetics	Welding Engineering
Geodetic Science	

Graduate education at the University is served by one of the most extensive library systems in the nation. The main library and the 21 department and college libraries contain 2.8 million volumes and receive 26,500 periodicals regularly. The entire library system is serviced by a computerized on-line circulation system that enables patrons to renew and check out books or periodicals via telephone. A mechanized information retrieval system enables faculty and graduate students to conduct literature surveys via computer. The libraries of

the Battelle Memorial Institute and Chemical Abstracts Service are in close proximity to the University and are open to both faculty and graduate students.

The University is one of the leading research centers in the nation. In fiscal year 1972, it ranked 18th nationally in total Federal Government research funding with \$23.07-million expended. In fiscal year 1974, The Ohio State University Research Foundation administered total expenditures of \$21.09-million for both government and non-government research. This level of funding included 750 projects which involved 450 full time faculty, 1074 investigators, 690 graduate students, and 364 supporting personnel. Graduate degrees earned by students engaged on sponsored research projects totaled 199 (119 masters and 80 doctorates).

Of the 20 colleges and other major University offices participating in sponsored research projects, there were three with more than 100 projects and six with total expenditures of more than \$1-million. Several of these are potential contributors to STS research programs.

The College of Medicine had 178 projects with total expenditures of \$5,003,288; the College of Engineering, 151 projects, \$4,110,186; and the College of Mathematics and Physical Sciences, 119 projects, \$2,614,429. Departments with expenditures of more than \$1-million included Electrical Engineering, 53 projects, \$1,785,830; Medicine, 53 projects, \$1,440,096; and Chemistry, 60 projects, \$1,424,244. Other departments with total expenditures of more than half-a-million dollars each included Physics, 20 projects, \$732,135; Metallurgical Engineering, 29 projects, \$544,276; Aeronautical and Astronautical Engineering, 21 projects, \$533,456; and Mechanical Engineering, 14 projects, \$507,975.

The College of Engineering ranks 8th nationally in total research expenditures with \$6.92-million expended in fiscal year 1973. This level of activity included both government and industry sponsored work. In this college, a total of 948 people were involved in 361 projects administered by both the Research Foundation and Engineering Experiment Station.

These levels of activity indicate both the breadth and the scope of research in progress at the University and the potential of the University to contribute to STS research programs in a wide range of disciplines.

A significant facility and staff which supports research projects throughout the University is the Instruction and Research Computer Center. The Center is one of the best equipped in the country. The current equipment consists of the following IBM computers: a 370/165, two 360/20's, an 1130, two 2760's, and a 1620. A number of remote console terminals are available throughout the campus as are an ample number of unit word machines. An analog to digital tape converter is provided for converting analog taped to digital tapes suitable for use

on digital computers. Paper tape handling equipment, two drum plotters, and a graphics display terminal, all of which are connected to computers are available.

II. THE LDEF RESEARCH PROPOSAL DEVELOPMENT PROGRAM AT OSU

The objectives of the LDEF research proposal development program at the University were,

1. To encourage as large a number of University faculty as possible to consider the potential for contributions in their fields by conducting long duration experiments in space.
2. To provide an effective mechanism for proposal development such that well defined research plans can be submitted to the LDEF program.
3. To encourage as large a number of University faculty in as wide a range of disciplines as possible to examine societal and scientific benefits of LDEF and Spacelab.

These objectives were achieved via solicitation of research prospectuses from the faculty of the departments listed in Part I and the award of small, but not insignificant, grants for development of some of the prospectuses into detailed research proposals. This process was implemented in two phases. The first phase was termed the "competition phase" wherein research prospectuses were reviewed and a decision was made for further funding on a competitive basis. The second phase was termed the "small grants phase" where actual awards of funds were made and used for proposal development at the discretion of the faculty member receiving the award. Research prospectuses submitted in the competition phase followed a two-page format developed by the OSU program coordinators. The research prospectuses submitted are presented in Appendix A. The research proposals developed in the small grants phases followed the ten-page format specified by NASA with supplementary information, e.g. faculty resumes, detailed discussions of special experimental requirements, etc., presented in appendices. The four research proposals developed in the small grants phase of the project are presented in Part III.

The competition phase extended over the first half of the project. Descriptive literature on STS and LDEF (see Appendix B) was developed and mailed to the faculty in the Summer and Fall Quarters of 1975. A blanket mailing to approximately 950 faculty members was made in the Summer Quarter. This was followed by a departmental mailing in the Fall Quarter. The existence of the program and an announcement of opportunity to participate was made in several campus publications.

Research prospectuses were reviewed by the project coordinators and other faculty members in appropriate scientific disciplines according to the following criteria:

1. The proposed research topic has sufficient specificity so that an experimental design with well defined objectives can be developed.

2. The proposed research topic possesses the potential for making a significant contribution to scientific knowledge.
3. The proposed research topic and experimental approach have a high probability of success if implemented for LDEF.

Four faculty members were awarded small grants for development of their research prospectuses into proposal form. Each of these awards was on the order of \$3,500, including indirect costs, and was used to cover a portion of the professor's salary for one quarter and/or a stipend to a graduate student for one to two quarters so that the proposal development could be done as part of normal work loads. During the proposal development phase, the project coordinators provided a liason between the faculty investigator and the OSURF and/or the LDEF Project Office at NASA-Langley. The project coordinators also served to provide technical assistance relative to implementation of experimental designs within the constraints of the LDEF.

III. SCIENTIFIC PROGRAMS PROPOSED FOR LDEF

A. Ultra Pure Germanium Gamma Ray Radiation
Detectors in the Space Environment

by

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EXPERIMENT TITLE: A Radiation Detection System Based on a High Purity Germanium (HPGe) Detector and a Diode Heat Pipe Cryogenic System Which Uses Space as a Heat Sink

EXPERIMENTERS: D. W. Miller, Ph.D., Associate Professor,
co-principal investigator
M. S. Gerber, Ph.D., Research Associate,
co-principal investigator
F. A. Kulacki, Ph.D., Associate Professor,
co-investigator
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TECHNICAL ABSTRACT:

The technological development of an x-ray and gamma-ray spectroscopy system incorporating a temperature cyclable high purity germanium (HPGe) detector and a diode heat pipe cryogenic system for cooling during operation is proposed. The introduction of HPGe radiation detectors permits the use of the intermittent cooling available from a diode heat pipe and radiator thermal system which uses deep space as the heat sink. This eliminates the requirement of an on-board heat sink, resulting in a low cost, lightweight spectroscopy system for space applications which has an extended usable operation time.

The need for a spectroscopy system to measure high energy photon radiation with precision energy resolution is well justified. The development of HPGe detector technology with heat pipe cooling will broaden the potential of gaining new insight into the universe through high energy photon characterization such as solar flares phenomena, stellar evolution and nuclear astrophysics. In addition, HPGe detectors, unlike presently used Na(Tl) and Ge(Li) detectors, can be fabricated into complex geometrical configurations such as required in telescopes and still maintain excellent energy resolving properties.

1.0 TECHNICAL DISCUSSION OF EXPERIMENT APPROACH, OBJECTIVE, JUSTIFICATION, AND BENEFITS.

The objective of the proposed research is to develop and space test a HPGe radiation detector-diode heat pipe spectroscopy system which utilizes space as a heat sink. The end result of the project is a high resolution x- and γ -ray measuring system which is not limited in its long-term use by the need for an on-board heat sink to cool the detector.

To obtain this objective, the authors have applied their expertise

and experience in space application of nuclear instrumentation, heat transfer, and HPGe detector fabrication to devise the following approach to fulfill the project objective. The measurement system is divided into three areas requiring analysis, design and development. They are the detector and its vacuum housing; the diode-heat pipe cryogenic system; and the instrumentation to analyze and record the detector operation characteristics and radiation spectrum in space.

In the area of detector fabrication and its vacuum housing, the technology is well developed. Planar HPGe detectors have been routinely fabricated at OSU for the past four years. A 2 cm. thick planar diode is proposed for this experiment because of its large detection area and therefore its excellent efficiency.

The diode-heat pipe cryogenic system¹ is the area in which technological development is needed. The developmental approach for the heat pipe entails the analysis, design, and prototype fabrication of the system. Preliminary design analysis shows that by using a radiator system looking into deep space which is coupled to a self-starting diode heat pipe and by properly shielding the detector, the detector can be cooled to an operating temperature of 80-100°K. Experiments performed at this laboratory have shown that for a HPGe detector the operating parameter of detector depletion voltage changes only a few percent over the temperature range of 80-200°K. These experiments have also shown that the degradation in energy resolution over that temperature range is slight and is almost entirely a function of increased detector leakage current at the higher temperature. This demonstration of minimal dependency on operating temperature for HPGe detectors enhances the concept of a diode heat pipe cryogenic system.

Based on a detailed design and analysis of the cryogenic system conducted as part of the first phase of the proposal, a prototype system will be fabricated and tested. From these results the design and specifications of the cryogenic system will be finalized. The fabrication of the system for space flight will be subcontracted to an organization with experience in fabrication of space components.

The instrumentation² required to monitor the detector operating parameters and perform x- and γ-ray radiation spectrum measurement is well defined. Some innovative concepts are required since the experiment needs to be self-contained and self-managing. Preliminary design of the instrumentation calls for the control of the experiment to be performed by a microprocessor system. Some of the operating functions the microprocessor will control will include monitoring the

¹More details on the preliminary analysis and design of the diode heat pipe cryogenic system are given in Appendix A.1.

²More details concerning the instrumentation design, specifications and cost are given in Appendix A.2.

detector temperature and taking proper action in terms of removing the detector bias voltage, periodically taking detector leakage current measurements as a function of bias voltage and detector temperature, monitoring and recording temperatures of interest such as the radiator temperature, and controlling the gathering and transfer of data to the tape recorders from the 4096 channel PHA.

The justification for measuring x- and γ -ray spectra is well developed in the literature. In the past, these measurements have been made using silicon solid state detectors for low energy (< 0.1 MeV) and NaI(Tl) scintillation detectors for higher energy. Both these detectors have disadvantages: silicon has poor efficiency and NaI(Tl) has poor energy resolution ($\sim 8\%$ at 0.662 MeV). Recently Ge(Li) detectors have been used in balloon and space vehicles. These experiments have been successful but limited in their time duration because of the need for an expensive, on-board heat sink. Herein lies not only the technical justification, but the benefits, for developing a HPGe detector diode heat pipe cryogenic system. It combines the high resolution, high efficiency properties of germanium detectors with long-term use in the space environment at a relatively low cost.

2.0 RELATED WORK AND EXPERIENCE

The engineering team assembled for the proposed program have experience in the critical areas necessary to complete the objectives of the experiment. The key personnel and their related experience are¹

D. W. Miller and M. S. Gerber -

Drs. Miller and Gerber are experienced in nuclear radiation detectors and instrumentation system design, fabrication and application. As a team, they have participated in several projects relating of this proposal. Specifically, these include the design, analysis and fabrication of the instrumentation for a HPGe γ -ray camera for nuclear medicine (funding for this project was provided by the National Institutes of Health (7/72-3/75) and the Picker Corporation (10/75-present) and the analysis and design of the readout instrumentation for a silicon spatial detector proposed for use in the Heavy Isotope Spectrometer Telescope (HIST) (this work was in support of a proposal submitted by Spacetic, Inc., Bedford, Massachusetts).

P. A. Schlosser -

Dr. Schlosser has directed the HPGe detector development for the germanium gamma camera program. He has been responsible for developing state of the art HPGe detector configurations. Dr. Schlosser has also

¹A complete list of research projects, publications, and presentations is given in the professional resumes of project investigators contained in Appendix B.

been involved in consulting relative to HPGe detector technology, and he has experience in the analysis and design of vacuum systems and cryogenic systems for HPGe detectors.

Drs. Miller, Gerber and Schlosser have collaborated on a number of papers, presentations and patent applications. Those pertinent to the proposed research are shown below:

Publications and Presentations:

"A Practical Gamma Ray Camera System Using High Purity Germanium," presented at the 1973 IEEE Nuclear Science Symposium, San Francisco, November 1973; also published in IEEE Trans. on Nuc. Sci., Vol. NS-21, No. 1, pp. 658-664, February 1974.

"A Prototype Gamma Camera System Based on a Strip-Electrode, High Purity, Germanium Detector," presented at the 1974 Society of Nuclear Medicine Meeting, June 1974; 1975 Annual Meeting of the Ohio Academy of Science, April 1975; 1976 ERDA Symposium on X- and Gamma-Ray Sources and Applications, May 1975; published in Symposium Transactions.

"Parallel-Hole Collimator Design," J. Nuc. Med., Vol. 15, pp. 724-725, August 1974.

"A Large Scale Medical Gamma Camera System Based on Orthogonal Strip, High Purity Germanium Detectors," presented at the IEEE Nuclear Science Symposium, Washington, D.C., December 1974.

"Instrumentation for a High Purity Germanium Position Sensing Gamma Ray Detector," IEEE Trans. on Nuc. Sci., Vol. NS-22, No. 1, pp. 416-421, February 1975.

"The Spatial Frequency Response of Orthogonal Strip Detectors," presented at the 1975 IEEE Nuclear Science Symposium, San Francisco; published in IEEE Trans. Nuc. Sci., Vol. NS-23, February 1976.

"Fabrication of Gamma Ray Detectors from High Purity Germanium," presented at the 1976 ERDA Symposium on X- and Gamma-Ray Sources and Applications, May 1976; published in Symposium Transactions.

Patent Applications:

"Gamma Ray Camera for Nuclear Medicine," Application Docket No. 2-081.

"Control System for Gamma Camera," Application Docket No. 2-086.

"Gamma Camera System with Composite Solid State Detector," Application Docket No. 2-087.

"Gamma Camera System," Application Docket No. 2-089.

F. A. Kulacki -

Dr. Kulacki has directed several research programs in the area of heat transfer. Specifically, he has directed projects in the study of heat source driven natural convection (sponsored by NASA); steady and natural convections in enclosed fluid layers with volumetric energy sources (sponsored by the USNRC); and coupled convective moment and mass transport from porous tubes in crossflow (sponsored by the NSF). In addition, Dr. Kulacki's teaching duties include advanced radiation heat transfer.

An abbreviated list of Dr. Kulacki's publications is shown below:

Kulacki, F. A., and Goldstein, R. J., "Thermal Convection in a Horizontal Fluid Layer with Uniform Volumetric Energy Sources," J. Fluid Mech., 55, 271, 1972.

Kulacki, F. A., and Goldstein, R. J., "Eddy Heat Transport in Thermal Convection with Volumetric Energy Sources," Paper NC 2.6, .. Proceedings, Fifth International Heat Transfer Conference, Tokyo, Japan, September 3-7, 1974.

Kulacki, F. A., and Goldstein, R. J., "Hydrodynamic Stability in Fluid Layers with Volumetric Energy Sources," Applied Sci. Res., 31, 81 (1975).

Kulacki, F. A., and Nagle, M. E., "Natural Convection in a Horizontal Fluid Layer with Volumetric Energy Sources," J. Heat Trans., 97C, 204-211, 1975.

Reif, T. H., Nerem, R. M., and Kulacki, F. A., "An In Vitro Study of Transendothelial Albumin Transport in a Steady State Pipe Flow at High Shear Rates," Advances in Engineering, eds. J. A. Brighton and S. Goldstein, 160-161, ASME, New York, 1974.

Kulacki, F. A., Emara, A. A., and Min, J. H., "Natural Convection in Internally Heated Fluid Layers - PAHR Applications," Proceedings, Post Accident Heat Removal Information Exchange Meeting, Sandia Laboratories, Albuquerque, New Mexico, November 13-14, 1975.

Kulacki, F. A., and Emara, A. A., "Heat Transfer Correlations for Use in PAHR Analysis and Design," Trans., American Nuclear Society, Vol. 22, pp. 447-448, November, 1975.

3.0 EXPERIMENT FACTS

3.1 What specific space properties will it make use of?

The natural heat sink property of the space environment will be used to cool the detector during operation. During operation the experiment will use the continuous and discrete x- and γ -ray radiation present in the space environment.

3.2 Preferred Location - Space end

3.3 Environmental Constraints

3.3.1 Temperature range -

On radiator where white paint is used,

$$\alpha/\epsilon = 0.3/0.8$$

$$T_{\min} \approx -173^{\circ}\text{C}; 100^{\circ}\text{K}$$

$$T_{\max} \approx 31^{\circ}\text{C}; 304^{\circ}\text{K}$$

Temperature for rest of experiment ambient

3.3.2 Vibration and shock -

Designed to LDEF and shuttle specifications

3.3.3 Attitude control -

Constrained by the requirements of temperature control

3.3.4 Radiation for the experiment -

It is desirable to have maximum x- and γ -ray flux. Charged particles entering the system will be electronically removed for the x- and γ -ray spectra.

3.3.5 Vacuum (space) -

Space vacuum is not required for the experiment. The detector will be housed in a sealed vacuum chamber.

3.3.6 Atmosphere -

Because the detector is housed in its own vacuum chamber, no pre-launch, during, post-launch, and return atmospheric requirements are anticipated.

3.3.7 Magnetic field -

The instrumentation package will be designed to operate in the magnetic field specified.

3.4 What special protection must be provided to protect the experiment from earth and space environments?

Although no special protection is required, minimizing the time the experiment is exposed to direct sunlight or earth shine would increase the detector cooling system efficiency and therefore increase the detector operating time.

3.5 Physical Description

3.5.1 Mass: 50 k Gram (estimated)

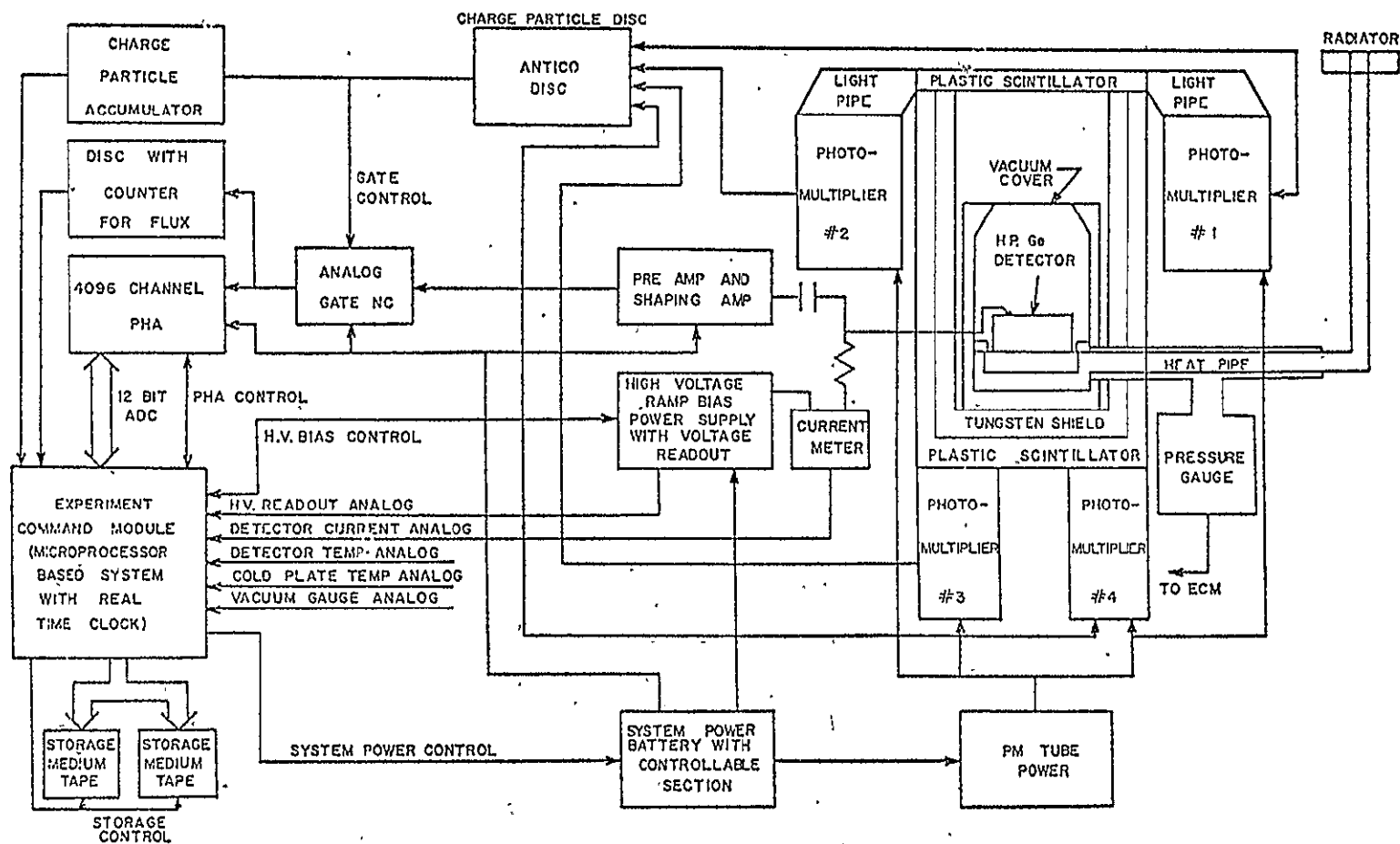
3.5.2 Volume: 2 ft³ (3456 in³)

Estimate that one 6-inch deep experimental tray is required.

3.5.3 Surface Area Required:

Estimate 1700 in² or approximately the exposed surface area of a 6-inch deep experimental tray.

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3.6 Sketch of Experimental Layout

4.0 EXPERIMENTAL HARDWARE

A sketch of the experimental system hardware is shown in section 3.6. This sketch combined with the discussion in this section demonstrates the method in which the experimental objective to develop and evaluate a HPGe-diode heat pipe spectroscopy system will be attained.

The diode heat pipe is shown in the upper right and is attached to a radiator external to the LDEF. This radiator will be designed to maximize the ϵ/α in order to take full advantage of space as a heat sink. The radiator is connected to a diode heat pipe (approximately 1000:1 thermal conductance) which again maximizes the cooling (i.e., energy rejection) by the system when coupled to the space heat sink through the radiator.¹ The heat pipe is then thermally coupled to the HPGe detector in order to provide cooling during operation.

The HPGe detector is housed in a vacuum chamber. The sides and bottom (the side facing into the LDEF) are shielded with tungsten. Surrounding the tungsten shield and facing the detector is a plastic scintillator to detect charged particles entering the system. The plastic scintillators are coupled to photomultiplier tubes through light pipes. The output of each tube is processed by an anti-coincidence circuit. If a signal is present from the photomultiplier tubes an analog gate is opened which stops the passage of signals from the germanium signal pulse shaping amplifier to the PHA.²

The experimental package is controlled by the Experiment Command Module (ECM). The ECM is a microprocessor based system with a real time clock, analog multiplexer sample and hold system which feeds an analog to digital converter. The analog signals are derived from temperature and pressure transducers as well as detector leakage current and detector bias voltage readings. The ECM will monitor the HPGe environment and take appropriate action. For example, if the temperature of the HPGe detector becomes greater than a preprogrammed temperature, the ECM will stop the γ -spectrum collection process; turn off the detector bias supply, transfer the spectrum being accumulated, the start and stop times of data collection, and the total number of charge particles counted to the tape storage; clear the system; and power down until the detector has returned to the proper operating temperature. During the power down phase, the ECM remains operational so that the detector, heat pipe and radiator temperatures can be measured.

The pulse height analyzer serves to reduce the gamma ray measurements to a distribution of the number of recorded gamma events versus

¹Details of the proposed heat pipe and thermal system are shown in Appendix A.1.

²Details of the instrumentation and experiment control system are shown in Appendix A.2.

energy. These results are then periodically transferred to one of the two tape storage mediums for analysis upon termination of the LDEF mission.

The entire system is powered by self-contained voltage sources shown in the blocks titled: (1) system power, (2) high voltage ramp supply, and (3) photomultiplier power. These voltage sources supply the power for the electronic system, HPGe detector, and photomultiplier tubes, respectively.

The instrumentation and system control system are state of the art. The diode heat pipe is also state of the art; however, the overall thermal system requires a development effort.

The above discussion briefly shows the methodology for fulfilling the proposed objectives and demonstrates the compatibility with the LDEF specification which requires total self containment and use of no external power or communication.

5.0 RESEARCH REQUIRED TO DEVELOP EXPERIMENT

The primary area of research required is the design and specifications of the cryogenic diode heat pipe for cooling the detector during operation. This will include laboratory measurements as required to specify geometric designs and materials. It is expected that the thermal system fabrication will be subcontracted per specifications based on the design analysis. A limited amount of additional work will be required in the design and specifications of the electronics package which will be subcontracted. The design and fabrication of optimum detectors will also be completed during the preliminary phase of the program.

6.0 PERMANENT EQUIPMENT AND SPECIAL FACILITIES

A cryogenic diode heat pipe will be purchased for thermal system design analysis. In addition, special apparatus will be constructed if a coaxial HPGe detector is used on the space flight. If a planar detector is used, it will be fabricated using facilities presently available at The Ohio State University.

7.0 COST ESTIMATE

7.1 Manpower -

	mm	\$
7.1.1 Experiment Design	62	117,561
7.1.2 Development of Implementation Plan	16	30,392
7.1.3 Ground-Based Testing	31	58,393
7.1.4 Pre-Launch Analysis	4	6,343
7.1.5 During Mission	7	12,861
7.1.6 Post-Launch Analysis	11	21,911

7.2 Hardware -

7.2.1 Engineering Prototype	25,000
7.2.2 Hardware Fabrication *	300,000
7.2.3 Pre- and Post-Launch	10,000

7.3 Other Direct Costs -

Computer, travel, etc.	9,000
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7.4 Total Costs

7.4.1 Manpower	131	247,461
7.4.2 Hardware		335,000
7.4.3 Other Direct Costs		9,000
7.4.4 Total		591,461

*Subcontracts for instrumentation \$150,000, thermal system \$125,000;
Misc. Components \$25,000

8.0 SAFETY CONSIDERATIONS

No potential hazards to ground or flight personnel, spacecraft or other experiments is anticipated.

9.0 INTERACTIONS WITH SPACECRAFT AND OTHER EXPERIMENTS

The experiment is entirely contained in one LDEF experiment tray with the exception of an external radiator. The LDEF tray will be located on the space end of the vehicle and no interaction with other experiments except for the remote possibility of thermal radiation shadowing from the radiator is expected.

10.0 SCHEDULE

Initiate Project (October 1, 1977)
Launch (January 1, 1980)
Final Report (December 30, 1980)

42 Month Program

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CALENDAR YEARS

MILESTONES		1975			1976			1977			1978			1979			1980			1981		
1	Thermal System Design & Analysis																					
2	Thermal System Subcontract																					
3	Instrumentation System Design and Analysis																					
4	Instrumentation System Subcontract																					
5	Experiment Implementation & Flight Plan Analysis																					
6	Fabrication & Assembly of Components																					
7	Ground Base Testing																					
8	Pre Launch Analysis																					
9	Mission																					
10	Post Launch Analysis																					
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Appendix A.1 Heat Pipe Cooling Radiator Feasibility Study

A preliminary feasibility study was undertaken to evaluate the concept of using a heat pipe-radiator cryogenic system for cooling the HPGe detector in the LDEF environment. This appendix summarizes that study.

A.1.1 Cooling System-Physical Geometry

The physical geometry for the detector-heat pipe cooling technique is shown in Figure A-1. The major components exemplified in Figure A-1 are the HPGe crystal, detector radiation shields, heat pipes, support board, experiment tray radiator and three radiation shields mounted between the LDEF and the radiator. The experiment tray is provided by the LDEF structure itself, and is described physically in the LDEF data sheet. The heat pipes depicted in the figure provide for heat transfer between the detector and external space radiator. The support board serves as a support for the external space radiator, and three LDEF radiation shields. The teflon rods shown in Figure A-1 serve as structural supports and were selected to minimize conduction heat transfer to the external radiator and LDEF radiation shields.

In order to minimize radiation heat transfer between the components shown in Figure A-1 and the LDEF, the components are specified as polished gold-coated aluminum which has extremely low inherent emissivities. However, the system model, to be described later, shows that with proper radiation shield design, conduction heat transfer dominates the overall system heat transfer for the geometry shown in Figure A-1.

The external radiator is selected such that it has an extremely low mass, high emissivity, and low absorptivity. The high emissivity and low absorptivity are achieved with a white paint specified in the LDEF data sheet. A low mass radiator is chosen since an extremely low inherent radiator time constant is desirable. The short external radiator time constant implies that the radiator will be very responsive to external heat loads placed upon it. Since moderately low temperatures ($< 730^{\circ}\text{K}$) are necessary for HPGe detector operation, and the orbit period for the LDEF is short, the system must have the ability to quickly achieve cryogenic temperatures. The short radiator time constant provides for this responsiveness.

The heat pipes depicted in Figure A-1 serve two functions. First, the heat pipes provide a thermal path between the detector and external radiator; second, they distribute the detector heat load over the entire area of the external radiator. The geometry for the heat pipes attached to the external radiator is shown in Figure A-1. The benefits associated with distributing the detector heat load over the external radiator are increased radiating area and increased radiator efficiency. The increase in radiator efficiency is derived from the fact that the temperature gradients over the area of the radiator are minimized, and therefore, the entire area is optimized in terms of radiating power.

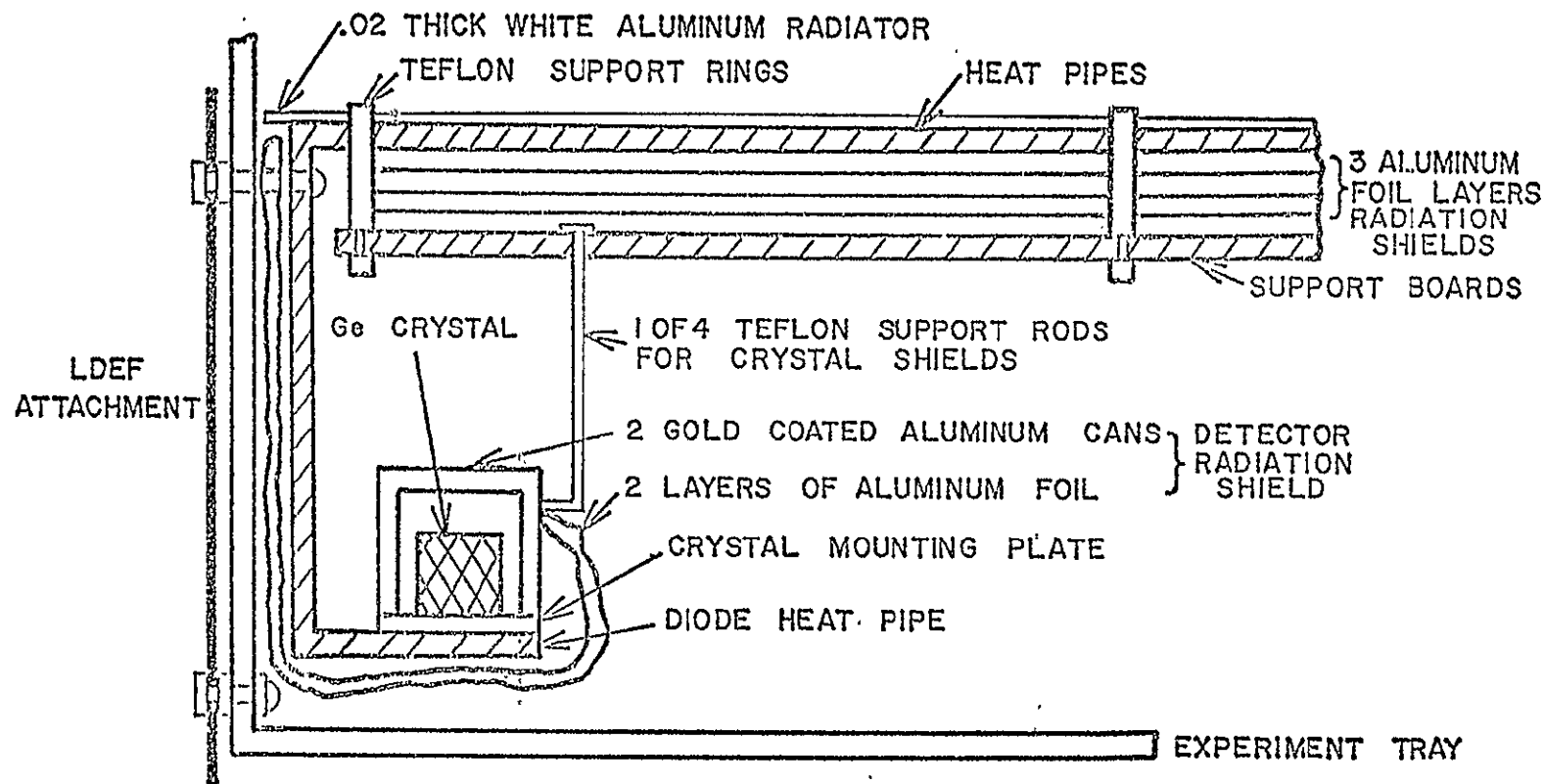


Figure A.1. Conceptual diagram of heat pipe cooling system.

The heat pipes are made of lightweight aluminum, and the working fluid is liquid nitrogen. The heat pipes have inherently low masses, and this means good response to external heat loads or sinks. The low masses inherent in the heat pipes is another major advantage that they offer over a solid conductor, since the lower the mass, the faster the response time.

The radiation shields provide for radiation shielding between the external radiator, and the support board and LDEF. The necessity for these radiation shields is based upon the need for the external radiator to achieve the desired temperature in the least amount of time. In this way, a heat sink is made available for cooling the detector in the short period of time dictated by the orbital period. No study was done on the number of shields that would optimize external radiator performance, but the results derived from the shields are definitely apparent. The radiation shields are simply thin sheets of aluminum foil stretched between the external radiator and support board.

All the cooling equipment components are thermally isolated from the LDEF structure by utilizing teflon supports. The objective in using teflon supports is to provide sufficient thermal isolation so that cryogenic detector operating temperatures are attainable. Thermally isolating the detector, heat pipe, and radiator system was one of the objectives of the design.

It must be mentioned that holes are cut into the radiation shields, support board, and external radiator so that the HPGe detector has an unattenuated view of space. However, attenuation by aluminum (low Z number) is negligible since only small attenuation thicknesses are involved (.02").

In summary, the major design objectives are thermal experimental isolation from the LDEF structure, and low component weight for minimum heat capacities and subsequent short response times. Other objectives are the minimization of radiation heat transfer between experimental components, and maximization of external radiator radiating power.

A.1.2 Major Design Considerations

One of the restrictions on the detector cooling system is its ability to rapidly respond to heat loads and sinks. This requirement is dependent on the 1.6 hr orbital period planned for the LDEF. Seventy percent of the orbit is spent in the sun, and in the other 30 percent the LDEF is shielded from the sun by the earth. It is evident that 0.48 hours to cool the detector down to cryogenic temperatures (77-126°K) is a strict requirement. However, this is not the only important consideration since at all times a great deal of earthshine is also experienced by the LDEF. For the cylindrical LDEF geometry, it is found that the earthshine will only permit an external radiator temperature of about 197°K for an experimental tray located on the side. Therefore, it is necessary to use a space end experimental tray for the

purpose of this experiment. The utilization of a space end tray eliminates the problem of earthshine, and the external radiator temperature is then only limited by space temperatures (30-100°K) which provides the necessary heat sink for the detector.

Another consideration involves the selection of the heat pipe design. The design selected for use in this particular application incorporates nitrogen as the working fluid, the container material is aluminum, and the wick structure is provided by axial grooves. The details of the particular one-inch diameter pipe chosen may be found in the Heat Pipe Design Handbook. The characteristic inherent in this particular pipe and important to the design is a maximum heat transport capability of 300 Watts for a one meter long pipe. However, one problem associated with the heat transport capability of the pipe is that the operating range is limited by the fluid properties of the working fluid. In this case, the critical temperature for nitrogen, 126°K, largely limits the heat transport capabilities of the pipe. Above 126°K, the heat pipe fluid only transports a minimum amount of heat, since at those temperatures nitrogen is incompressible. The majority of heat will be transferred through the walls of the pipe above 126°K. Below 126°K, the heat pipe operates in the designed manner, and the fluid transfers the majority of heat through the pipe. It is evident that a design problem evolves from this discussion, since it must now be determined whether the heat pipe attains workable operating temperatures after being exposed to the sun and earthshine radiation heat loads for 70% of the orbital period. The importance of the heat pipes attaining operating temperatures is obvious due to the fact that their heat transport capabilities are reduced greatly (approximately a factor of 1000) when they are not operable. However, one advantage of the low nitrogen critical temperature is the fact that heat is not transported to the detector by the pipe when the external radiator and attached pipes are above 126°K. As a consequence, the pipe is operated as a diode in that it only conducts energy unidirectionally from the detector to the external radiator.

The physical system described in the previous paragraphs was computer modelled in order to evaluate whether, during the period in which the LDEF is in the earth's shadow, the detector can be cooled to the operating temperature.

In the model, the component temperatures were selected based on the known LDEF operating temperatures in orbit about the earth. The values chosen were conservative so that feasibility under these conditions implies a design margin. All the initial component temperatures are at least as high as the space end maximum design temperature of 500°R. The experimental tray temperature is held constant at 500°R to simulate the worst case LDEF temperature.

The variation of component temperatures with time were calculated with the sun flux on the radiator set to zero. The program shows that

for the parameters chosen the detector will cool to operating temperatures in about 12 minutes.

The conclusion drawn from the study is that if the experimental heat pipes, external radiator, and detector can be thermally isolated from the LDEF, cryogenic detector temperatures will be possible. The major problem inherent in the program is the assumption of overall contact conductances between components. These values were chosen conservatively to merit the decision that the detector cooling system is indeed feasible. More detailed analysis is necessary in order to ascertain the exact nature of the system response for the geometry proposed.

Appendix A.2 Proposed Specifications for Experiment Electronics

This appendix includes specification lists of the proposed LDEF experiment. It was submitted to Spacetac, Inc., a space electronics firm, for comment, cost estimates, and weight estimates. Their response to the proposed experiment specifications given in the following paper and the block diagram of the experimental layout shown in Section 3.6 is enclosed.

OSU LDEF EXPERIMENT SPECIFICATIONS

Submitted to Spacetac, Inc.

I. Objective

The objective of this experiment is to evaluate the use of high purity germanium (HPGe) radiation detectors for long-duration space missions; and, since HPGe detectors need to be cooled to cryogenic temperatures only during use, to evaluate using a diode heat pipe with a radiator system to cool the detector.

II. System Information Output

Using a tape storage medium, the following information will be recorded:

- A. 4096-channel γ -ray spectrum on an hourly basis with the data collection start and stop times.
- B. Germanium detector flux counts/unit area/unit time.
- C. Temperature of the heat pipe radiator system and the HPGe detector vs. time to measure the diode effect of the heat pipe and the heat transfer characteristics.
- D. Temperature vs. time of the HPGe detector to protect the detector from operating at a temperature greater than 130°K.
- E. Pressure vs. time in the detector vacuum housing.
- F. Detector leakage current vs. detector bias voltage to check I-V properties as a function of time and temperature.
- G. Number of charged particles counted per hour during γ -ray spectrum accumulation.

III. System Functions

The system is designed to make the above measurements. The HPGe detector is housed in a vacuum chamber. The sides and bottom (the side facing into the LDEF) are shielded with tungsten. Surrounding the tungsten shield and facing the detector is a plastic scintillator to detect charged particles entering the system. The plastic scintillators are coupled to photomultiplier tubes through light pipes. The output of each tube is processed by an anti-coincidence circuit. If a signal is present from the photomultiplier tubes an analog gate is opened which stops the passage of signals from the germanium signal pulse shaping amplifier to the PHA.

The experimental package is controlled by the Experiment Command Module (ECM). The ECM is a microprocessor based system with a real time clock, analog multiplexer sample and hold system which feeds an analog to digital converter. The analog signals are derived from temperature and pressure transducers as well as detector leakage current and detector bias voltage readings. The ECM will monitor the HPGe environment and take appropriate action. For example, if the temperature of the HPGe detector becomes greater than 130°K the ECM will stop the γ -spectrum collection process; turn off the detector bias supply; transfer the spectrum being accumulated, the start and stop times of data collection, and the total number of charge particles counted to the tape storage; clear the system; and power down until the detector has returned to the proper operating temperature. During the power down phase, the ECM remains operational so that the detector and heat pipe radiator temperature can be measured.

IV. System Components, Functions, and Specifications

In this section, a brief description of each component in the system, its function, and its specifications will be given.

A. Detector, Detector Housing, and Shielding

1. High Purity Germanium Detector

- a. ~ 50 cc volume
- b. geometry; coaxial or planar (TBD)

2. Plastic Scintillator

Surrounds the HPGe detector, vacuum can, and tungsten shield. Connected to photomultiplier tubes through light pipes.

3. Detector Housing

The HPGe detector is supported by a metal (TBD) cold finger which is connected to the heat pipe. The detector, cold finger and part of the heat pipe are housed in an aluminum vacuum can with a thin ~.020" γ -ray entrance window. The cold finger temperature and vacuum can internal pressure are to be monitored.

4. Shielding

The vacuum can is shielded, except for the entrance window, by tungsten. The gm/cm² spec is TBD.

B. Electronic Equipment

1. 4 - photomultiplier tubes
possible type RCA C70114F
2. 1 - low noise preamplifier with Gaussian Shaping filter (filter time constant TBD). Shaping amplifier should have excellent overload recovery properties.
3. 1 - high voltage ramp on-ramp off power supply (0-2 kV) with analog voltage readout and analog current readout. These signals are read by the ECM's analog section.
4. 1 - normally closed analog gate.
5. 1 - anti-coincident/discriminator (ANTICO/DISC) circuit. This circuit measures the output of the photomultiplier tubes and decides if a charged particle has entered the detector area. If so, the analog gate is opened.
6. 1 - charged particle counter. This circuit is a 14-16 (TBD) bit counter which counts the number of gate control pulses from the ANTICO/DISC circuit. At the end of each spectrum data gathering period, the count information is sent to the ECM for formatting and transmittal to the tape storage.
7. 1 - γ -ray counter with energy discriminator to measure incident γ -ray energy flux. If the flux level for a spectrum count period is too low, the spectrum is discarded.
8. 4096-Channel PHA

A low A-D clock frequency is needed, ~1-2 MHz. The address word is passed to the ECM.
9. Power Supplies
 - a. A controlled system power supply (CSPS) is provided (i.e. batteries). The CSPS supplies power to other DC-DC converters which in turn supply the P. M. tubes, the HPGe detector bias, and the electronics, except the ECM. This supply is controlled by the ECM for power down states.
 - b. The ECM has its own power supply which can be sectionalized to power-on only the storage and memory required (TBD). The ECM also controls the tape

10. Experiment Command Module (ECM).

The ECM is the control center of the experiment. The six-month experimental sequence is stored in an array of read only memories (ROM). The ECM responsibilities include:

- a. Monitoring the detector temperature
- b. Monitoring the cold plate (radiator) temperature
- c. Based on detector temperature measurement, take required control action, i.e. if temperature is greater than 130°, the high voltage bias supply is ramped off.
- d. Provide the memory for the 4096 PHA
- e. Provide real time clock
- f. Monitor detector vacuum can pressure
- g. Monitor detector high voltage bias
- h. Monitor detector leakage current
- i. Interface all data to the tape recorders
- j. Control system power supplies
- k. Control high voltage HPGe bias supply
- l. Perform the monitoring functions in random time as determined by flag situations

The type of studies which will be stored on the data tape include:

- a. The γ -ray spectrum from the 4096 PHA
- b. Detector Leakage Current vs. Detector Bias Voltage at temperatures less than 130°K
- c. Detector Leakage Current vs. Detector Temperature at a 10 V detector bias
- d. Charged particles counted during γ -ray spectrums
- e. Cold Plate Temperature vs. Detector Temperature
- f. Vacuum can pressure

g. HPGe detector particle flux

h. LDEF temperature

i. Calibration spectrum

IV. General Specifications

γ Energy Range: 0.05-5 MeV

Calibration: On board Ba¹³³ γ -ray source for system calibration

Signal reference potential at HPGe ground

Response of Spacetac, Inc.
for
OSU LDEF EXPERIMENT, ELECTRONIC EQUIPMENT

I. Summary

Spacetac proposes to implement the OSU LDEF experiment electronics using low power circuitry with previous reliable space flight performance. The fact that this system must get all its power from batteries underlines the necessity of low power operation. This proposal will outline the approach taken to meet all the specification requirements and summarize our power and weight estimate. The goal of this effort is to provide OSU with a reliable, low-power system capable of performing for the entire 6 month mission.

II. Analog Processing Electronics

The analog processing electronics would be ideally implemented using Spacetac's low-power module technique. The preamplifiers will be chosen from existing designs, the shaping times to be determined later. The discriminators and coincidence logic would use low-power ECL modules. The 4096 channel PHA would be identical to that used on the Mariner Jupiter Saturn probe electronics. At a peak power of 40 mw, this analyzer will resolve to 2 mv. and maintain a differential non-linearity of $\pm 1.0\%$ and an integral non-linearity of $\pm 0.1\%$ over the top 99%. The digitizing clock is 4 MHz.

III. Experiment Command Module

The experiment command module will be a microprocessor based central controller. It will be responsible for data handling, power supply control and interfacing. Since the controller must remain active during the entire six-month experimental sequence, a C-MOS logic microprocessor will be employed. (A likely candidate is the RCA COSMAC 16-bit CPU whose maximum operating power consumption is 32 mw.)

There will be three types of data presented to the ECM from the linear electronics: PHA, rate and housekeeping. The PHA data will be stored in a 4096 x 16 CMOS RAM to form a histogram of events. This spectrum will be inputted to the tape recorder once every hour. The rate data will consist of total charged particles counted and HPGe detector particle flux. Each rate will be stored in C-MOS accumulators and read out each hour with the PHA data. The third type of data processed by the ECM will be the analog housekeeping levels, consisting of: high voltage, detector current, detector temperature, cold plate temperature and vacuum

III. Experiment Command Module (Continued)

guage. These levels will be multiplexed into a single eight bit successive approximation C-MOS A to D converter. A time profile for each hour could be stored in two 256 x 4 C-MOS RAMS for all five measurements. This data would also be inputted to the tape recorder each hour.

The controlling aspect of the ECM will consist of powering down sections of the experiment when certain programmed limits are exceeded. If the environment requires the ECM to power down the experiment, it will input the status of all data logging accumulators and stop time to the tape recorder. The ECM will remain operational, monitoring the temperatures during the power down cycle so that the system can start up again when the temperatures return to nominal. The software program for the controller will be stored in a 256 x 4 C-MOS PROM. To complete the microprocessor hardware a 512 x 4 scratch pad RAM memory is also required.

IV. Tape Recorder

There presently exists only two space-qualified NASA standard tape recorders, manufactured by RCA and Odetics. Either device would support the OSU experiment. Assuming a 4096 x 16 PHA histogram and a 512 x 8 time vs. housekeeping data histogram read out every minute for three months (50% duty cycle over six months), 1.5×10^8 bits of data storage is required. The standard units store 4.5×10^8 and 10^9 bits respectively.

Since the NASA standard tape recorders feature an in-space playback capability, there is much circuitry and hardware that can be eliminated for this mission. Accordingly the estimates used for power and weight (5 w. and 4 Kg.) are lower than the standard unit as they reflect these changes.

V. Power Supplies

In order to choose a battery to power the instrument for the entire mission, a power drain estimate was made. A total energy requirement of 96 ampere-hours was estimated. 28 volts was chosen for the battery voltage since the tape recorder requires it and also most spacecraft DC to DC converters are designed to run on 28 v. The battery chosen is a silver-zinc 130 amp-hr. 18 cell unit. This unit has previous balloon flight history, total size 8" x 14" x 6" and weighs 42 lbs. (20 Kg.)

The required DC to DC converters were all chosen from previous Spacetic designs. The four photomultiplier supplies are identical to units which have flown many times before. The 2 Kv. bias supply is also a proven design as is the low voltage converter. Since the high voltage supplies will run on voltages generated by

V. Power Supplies (Continued)

the low voltage converter, the controlling circuitry for powering down the instrument will be in the primary of the low voltage converter. One section will remain running for the ECM.

VI. Reliability and Quality Assurance

The NASA LDEF Program has advised on the use of an experiment assurance procedure for the mission. This procedure requires the experimenter to take appropriate considerations to assure that the experiment will reliably perform its function and do so without affecting other experiments on the LDEF. With this in mind, Spacetac would propose to use established reliability, military grade hardware and employ design and fabrication practices consistent with space flight hardware.

TABLE I
Power Breakdown

<u>Unit</u>	<u>Power</u>	<u>Avg. Percentage Use</u>
Microprocessor	32 mw	100%
EPROM	10 mw	100%
RAM's	1 mw	100%
Temperature Monitors	2 mw	100%
Photomultiplier Preamps	40 mw	50%
Ge Preamp	20 mw	50%
Discriminators	25 mw	50%
4096 PHA	50 mw	50%
Control Circuitry	35 mw	50%
Tape Recorder	5 w	0.5%

Adding in the inefficiencies of the power supplies, total energy required for six months is 96 ampere-hours.

TABLE II
Weight Breakdown

<u>Unit</u>	<u>Weight</u>
Battery	20 Kg
Tape Recorder	4 Kg
Low Voltage Converter	250 g
P.M. Supplies (4)	600 g
Bias Supply	200 g
Linear Electronics	1 Kg
ECM	4 Kg
 TOTAL	 30 Kg

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Appendix B

Resumés

PROFESSIONAL RESUME

1. NAME: PHONE:

Don Wilson Miller
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Home: (614)891-1858
Office: (614)422-7979

2. PRESENT POSITION:

Associate Professor of Nuclear Engineering, The Department of
Mechanical Engineering, The Ohio State University, Columbus,
Ohio

3. PERSONAL:

Born: [REDACTED]
Married: Mary
Children: Amy, Stacy, Paul
Social Security No.: [REDACTED]

4. DEGREES:

B.S. - Miami Univ., Oxford, Ohio, June 1964, Physics
M.S. - Miami Univ., Oxford, Ohio, August 1966, Physics
M.S. - The Ohio State Univ., Columbus, Ohio, August 1970,
Nuclear Engineering
Ph.D. - The Ohio State Univ., Columbus, Ohio, June 1971,
Nuclear Engineering

5. HONORS:

Culler Prize Award, Miami University, 1961
Sigma Pi Sigma, 1962
Phi Eta Sigma, 1962
University Fellowship, The Ohio State University, 1968
Certificate for Special Services Rendered to the American
Nuclear Society, 1969
Nuclear Engineering Distinguished Service Award, The Ohio
State University, 1970

6. PROFESSIONAL EXPERIENCE:

Research Engineer, Missile and Guidance System Division,
North American Aviation, 1963 and 1964.

Teaching Assistant, The Department of Physics, Miami Univer-
sity, 1964-1966. Taught undergraduate physics laboratories.
Developed senior electronics laboratory.

Research Associate, 1966-68, University Fellow, 1968-69, Teaching Associate and Instructor, 1969-71, Nuclear Engineering Section, The Department of Mechanical Engineering, The Ohio State University. Participated in research contract directed to the investigation of ferroelectric radiation detectors. Taught lecture and laboratory courses in nuclear instrumentation, and feedback and control. Member of several departmental committees.

Assistant Professor, The nuclear Engineering Section, 1971-1974. Taught Introduction to Nuclear Science and Engineering, Nuclear Instrumentation, Reactor Laboratory, Introduction to Heat Transfer and Mechanical Engineering Laboratory. Initiated course in Random Noise Analysis of Nuclear Systems. Member of several departmental and university committees, including Co-Chairman of Laboratory Development Committee.

Associate Professor, The Nuclear Engineering Section, 1974 - Initiated courses in nuclear reactor instrumentation and reactor operators training. Taught Nuclear and Mechanical Engineering courses. Member of several departmental and university committees. Coordinator of Nuclear Engineering undergraduate programs.

7. CONTRACT RESEARCH:

Research Associate, "Development of Ferroelectric and Ferromagnetic Radiations Detectors," July 1966-June 1970 (\$100,000). Sponsor: Edgewood Arsenal and Department of Defense.

Co-Principal Investigator and Supervisor, "A New Semiconductor Gamma Camera for Nuclear Medicine," July 1972-February 1975 (\$299,000). Sponsor: National Institutes of Health.

Co-Principal Investigator and Supervisor, "Development of Pyroelectric Field Effect Detectors," June 1973-March 1975 (\$25,000). Sponsor: Advanced Research Projects Agency and Ft. Belvoir.

Co-Principal Investigator and Supervisor, "Development of a Data Acquisition System to Interface a Scintillation Gamma Ray Camera and an IBM 370 Computer," July 1974-September 1975 (\$41,650). Sponsor: The Ohio State University Hospitals and Providence Hospital, Seattle, Washington.

Co-Principal Investigator and Supervisor, "Evaluation of Metering and Related Technical Aspects for Improved Electric Utility Rate Structures," June-September 1975 (\$9,900). Sponsor: Public Utilities Commission of Ohio.

Principal Investigator, "Ultra Pure Germanium Gamma Ray Radiation Detectors in the Space Environment," October 1975-March 1976 (\$3,544). Sponsor: National Aeronautical and Space Administration.

Co-Principal Investigator and Project Supervisor, "Development of a Germanium Gamma Ray Camera System for Nuclear Medicine," October 1975-September 1976 (\$180,000); October 1976-September 1978 (\$429,250) contingency contract. Sponsor: The Picker Corporation.

Co-Principal Investigator and Group Leader, "Corporate Finance Model," November 1975-October 1976 (\$65,000). Sponsor: Public Utilities Commission of Ohio.

8. PROFESSIONAL AND SCIENTIFIC ORGANIZATIONS:

American Nuclear Society, 1966 -
American Nuclear Society/Southwestern Ohio Section, 1971- ;
Program Committee, 1971; Membership Chairman, 1973-75;
Treasurer, 1975-76.
American Society for Engineering Education, 1972- ;
Board of Directors, Nuclear Engineering Division, 1973-75.
Co-Editor of Newsletter, 1975-76.
Instrument Society of America, 1972-
Institute of Electrical and Electronics Engineers, Inc.,
1974-

9. PATENT DISCLOSURES:

"Ferroelectric Field Effect Device," February 1972.
"Acoustic Noise Dosimeter," September 1973 (with L. L. Faulkner and D. D. Glower).
"Developments Relating to an Improved Gamma Ray Camera System for Nuclear Medicine Based on Orthogonal Strip Germanium Detectors with Charge Splitting Signal Readout," filed September 1975 with The Ohio State University Research Foundation (with other co-inventors).
"Row-Column Area Readout Method for Position Sensitive Detectors," filed September 1975 with The Ohio State University College of Engineering (with M. S. Gerber).
"A Method of Forming a Continuous, Charge-Splitting Resistive Layer on Grooved or Grooveless Orthogonal Strip Semiconductor Detectors," filed October 1975 with The Ohio State University College of Engineering (with P. A. Schlosser, M. S. Gerber, A. S. Zolnay, and J. W. Steidley).

10. PUBLICATIONS:

D. W. Miller and G. W. Caudill, "Driving Mechanism for a Foucault Pendulum," American Journal of Physics, 34, No. 7,

615-16, July 1966.

D. W. Miller, P. A. Schlosser, J. Burt, D. D. Glower, and J. M. McNeilly, "A Pulsed Radiation Energy Spectrometer Using Ferroelectrics," IEEE Transactions on Nuclear Science, NS-14, No. 6, 245-51 (December 1967).

D. D. Glower, D. W. Miller, and P. A. Schlosser, "The Use of Ferroelectrics in the Detection of Nuclear Radiation," International Journal of Nondestructive Testing, 1, 191-212 (1969).

P. A. Schlosser, D. W. Miller, and D. D. Glower, "The Theory and Application of Ferroelectric Radiation Detectors," International Journal of Nondestructive Testing, 2, 19-20 (1969).

D. W. Miller and D. D. Glower, "The Properties of Oxygen Depleted Ceramic $\text{Pb}(\text{Zr}_{.65}\text{Ti}_{.35})\text{O}_3 + 1 \text{ wt\% Nb}_2\text{O}_5$ Surface Layers," Ferroelectrics, 3, 295-301 (February 1972) and IEEE Trans. Sonics and Ultrasonics, SU-19, 295-301 (February 1972).

P. A. Schlosser, D. W. Miller, et al., "A Practical Gamma Camera System Using High Purity Germanium," presented at the 1973 IEEE Nuclear Science Symposium; published in IEEE Trans. on Nuc. Sci., NS-21, No. 1, 658-664 (February 1974).

M. S. Gerber and D. W. Miller, "Parallel-Hole Collimator Design," J. Nucl. Med., 15, 724-725 (August 1974).

D. W. Miller, "Direction of Nuclear Engineering Education," ASEE Nuclear Engineering Division Newsletter, October 1974 (Guest Editor).

M. S. Gerber, D. W. Miller, B. M. Gillespie, and R. S. Chemistruck, "Instrumentation for a High Purity Germanium Position Sensing Gamma Ray Detector," IEEE Trans. Nuc. Sci., NS-22, No. 1 (February 1975).

A. H. Deutchman, D. W. Miller and W. W. Hunter, Jr., "Quantitative Dynamic Radiotracer Imaging: The Design and Applications of a Clinically Practicable System," presented at the 1974 IEEE Nuclear Science Symposium, published in IEEE Trans. Nuc. Sci., NS-22, No. 1 (February 1975).

J. W. Steidley, D. W. Miller, P. A. Schlosser, M. S. Gerber and A. H. Deutchman, "The Spatial Frequency Response of Orthogonal Strip Detectors," presented at the 1975 IEEE Nuclear Science Symposium, to be published in IEEE Trans. Nuc. Sci., NS-23, No. 1 (February 1976).

11. PRESENTATIONS AND ABSTRACTS:

D. W. Miller, P. A. Schlosser, et al., "A Prototype Gamma Camera System Based on a Strip-Electrode, High Purity Germanium Detector," presented at the 21st Annual Society of Nuclear Medicine Meeting, June 1974.

G. H. Miley, M. Becker, D. W. Miller and M. J. O'Hanian, "Nuclear Engineering Education," panel discussion presented at the 1974 Annual Meeting of the ASEE, June 1974.

P. A. Schlosser, M. S. Gerber, D. W. Miller and A. H. Deutchman, "A Large Scale Medical Gamma Camera System Based on Orthogonal Strip, High Purity Germanium Detectors," presented at the 1974 IEEE Nuclear Science Symposium, December 1974.

D. W. Miller, P. A. Schlosser, M. S. Gerber and H. H. Deutchman, "A Prototype Gamma Ray Camera for Nuclear Medicine Based on a High Purity Germanium Detector," presented at the 84th Annual Meeting of The Ohio Academy of Science, April 1975.

D. W. Miller and F. A. O'Hara, "Nuclear Power," workshop presentation sponsored by The Ohio Power Siting Commission, June 1975.

A. H. Deutchman, L. R. Fulmer, G. R. Wise, W. W. Hunter, Jr., and D. W. Miller, "A Clinically Practicable Procedure for the Quantitative Evaluation of Regional Cerebral Circulation," presented at the 22nd Annual Society of Nuclear Medicine Meeting, June 1975.

D. W. Miller and M. S. Gerber, "Metering and Related Technical Aspects for Implementing Improved Electric Utility Rate Structures," workshop presented at the Public Utilities Commission of Ohio, November 1975.

12. REPORTS AND THESES:

D. W. Miller, "Instrumentation for Angular Correlation Experiment," Miami University, Master's Thesis (unpublished), 1966.

D. D. Glower, D. W. Miller and P. A. Schlosser, "Development of Ferroelectric Nuclear Radiation Detectors," U.S. Army Defense Laboratory NDL-TR-110, June 1968.

D. W. Miller, "Ferroelectric Field Effect Studies Utilizing Oxygen Depleted Lead Zirconate Titanate Surface Layers," Ph.D. Thesis (unpublished), 1971.

R. F. Redmond, W. W. Hunter, Jr., D. W. Miller, P. A. Schlosser, M. S. Gerber, "To Develop a New Semiconductor Gamma

Camera System for Nuclear Medicine," Final Report to The Department of Health, Education, and Welfare, National Institutes of Health, National Institute of Neurological Diseases and Stroke, June 1975.

A. S. Zolnay and D. W. Miller, "Development of Pyroelectric Field Effect Radiation Detector for Use in Infrared Sensing and Imaging Devices, Final Report, Contract No. DAAK02-73-C-0366, Night Vision Laboratory, Ft. Belvoir, Virginia, June 1975.

D. W. Miller, M. S. Gerber, R. E. Redmond, G. C. Ficke, J. R. Rusick, and B. K. Utts, "Evaluation of Metering and Related Technical Aspects for Implementing Improved Electric Utility Rate Structures," Final Report to the Public Utilities Commission of Ohio, October 1975.

13. SPECIAL PROFESSIONAL ACTIVITIES:

Chairman of the Finance Committee for the Midwest Student American Nuclear Society Conference (1969).

Adviser in NSF High School Summer Training Program (1971) (1973).

Adviser, OSU Student Section of the American Nuclear Society, 1972- .

Speaker at numerous high schools, 1972-1975.

High School Science Fair Judge, Local, District and State Fairs (1972) (1973).

Adviser, OSU Undergraduate Engineering Research Scholarship Recipient (John W. Steidley) (1972-1973).

Session Chairman, Nuclear Division, 1975 ASEE Annual Conference.

Invited Seminar Speaker, Miami University (1974) and Wittenberg University (1974).

Invited Speaker, Westerville Rotary Club (1974).

Invited Speaker, OSU College of Engineering, "A Day on Campus," (1975).

14. CONSULTING EXPERIENCE:

Battelle Memorial Institute, Columbus, Ohio, 1973-75 (X-ray Radiation Detection).

Physics International, San Leandro, California, 1973 (X-ray Radiation Detection).

The Picker Corporation, North Haven, Connecticut, 1975-76 (Gamma Ray Camera Development)..

The Ohio Power Siting Commission, Columbus, Ohio, 1973-75 (informal advisor).

Spacetac, Inc., Bedford, Massachusetts, 1975 (Instrumentation Design Analysis).

15. SPECIAL NONPROFESSIONAL ACTIVITIES:

Board of Directors and Committee Member, Concord, Drug Abuse and Crisis Intervention Center, Westerville, Ohio, 1974-

Scholarship and Outreach Committees, The First Presbyterian Church, Westerville, Ohio 1974-1975.

Board of Directors, The Cellar Lumber Co., 1973-

Board of Directors, Westerville Interiors, Inc., 1974-

Elected Member of the Westerville Board of Education, November 1975; January 1976-December 1979 term.

PROFESSIONAL RESUME

1. NAME: Mark S. Gerber PHONE: Home: (614)486-3009
 1170 Chambers Rd., #23A Office: (614)422-8150
 Columbus, Ohio 43212

2. PRESENT POSITION: Research Associate, Nuclear Engineering
 Section, Department of Mechanical Engineering,
 The Ohio State University

3. PERSONAL:

Born: [REDACTED]
Social Security No.: [REDACTED]

4. DEGREES:

BS - Mathematics, Worcester Polytechnic Institute, June 1969
MS - Nuclear Engineering, The Ohio State University, June 1970
PhD - Nuclear Engineering, The Ohio State University, June 1975

5. HONORS:

Honorary Societies: Pi Mu Epsilon, 1968
BS with distinction, 1969
Who's Who Among Students in American Colleges and Universities,
1969
Nuclear Engineering Distinguished Service Award, 1974, The Ohio
State University

6. PROFESSIONAL EXPERIENCE:

Nuclear Engineering Section, Department of Mechanical Engineering,
The Ohio State University

Graduate Research Associate - 6/69-8/69. Participated in
research contract directed to the investigation of methods
for measuring the reactivity of nuclear reactors.

AEC Trainee and University Fellow - 9/69-8/73. Participated
in research directed to the investigation of soft x-rays
generated by exploding wires (9/70-12/71) and in research
directed to the development of a semiconductor gamma ray
camera (5/72-8/73).

Graduate Research Associate - 9/73-6/75. Participated in
contract research. Taught laboratory section for nuclear
instrumentation. Supervised the research of master's students.
Served as President of The Ohio State Student Branch of the

American Nuclear Society.

Research Associate - 6/75- . Participated in contract research. Supervise the research of students.

7. CONTRACT RESEARCH:

Graduate Research Associate, "A New Semiconductor Gamma Camera for Nuclear Medicine," July 1972-February 1975 (\$299,000). Sponsor: National Institutes of Health.

Graduate Research Associate, "Development of a Data Acquisition System to Interface a Scintillation Gamma Ray Camera and an IBM 370 Computer," July 1974-September 1975 (\$41,650). Sponsor: The Ohio State University Hospitals and Providence Hospital, Seattle, Washington.

Investigator, "Evaluation of Metering and Related Technical Aspects for Improved Electric Utility Rate Structures," June-September 1975 (\$9,900). Sponsor: Public Utilities Commission of Ohio.

Investigator, "Ultra Pure Germanium Gamma Ray Radiation Detectors in the Space Environment," October 1975-March 1976 (\$3,544). Sponsor: National Aeronautical and Space Administration.

Investigator and Group Leader, "Development of a Germanium Gamma-Ray Camera System for Nuclear Medicine," October 1975-September 1976 (\$180,000); October 1976-September 1978 (\$429,250) contingency contract. Sponsor: The Picker Corporation.

Investigator, "Corporate Finance Model," November 1975-October 1976 (\$65,000). Sponsor: Public Utilities Commission of Ohio.

8. PROFESSIONAL AND SCIENTIFIC ORGANIZATIONS:

American Nuclear Society, 1969
Institute of Electrical and Electronics Engineers, 1973
Southwestern Ohio Section of the American Nuclear Society, 1976

9. PUBLICATIONS:

P. A. Schlosser, D. W. Miller, M. S. Gerber, R. F. Redmond, J. W. Harpster, W. J. Collis, and W. W. Hunter, Jr., "A Practical Gamma-Ray Camera System Using High-Purity Germanium," presented at the 1973 IEEE Nuclear Science Symposium, San Francisco, November 1973; also published in IEEE Trans. Nucl. Sci., Vol. NS-21, No. 1, pp. 658-664, February 1974.

M. S. Gerber and D. W. Miller, "Parallel-Hole Collimator Design," J. Nucl. Med., Vol. 15, pp. 724-725, August 1974.

M. S. Gerber, D. W. Miller, B. S. Gillespie, and R. S. Chemis-truck, "Instrumentation for a High Purity Germanium Position Sensing Gamma Ray Detector," IEEE Trans. Nuc. Sci., Vol. NS-22, No. 1, p. 416, February 1975.

J. W. Steidley, D. W. Miller, P. A. Schlosser, A. H. Deutchman, and M. S. Gerber, "The Spatial Frequency Response of Orthogonal Strip Detectors," presented at the 1975 IEEE Nuclear Science Symposium, to be published in IEEE Trans. Nuc. Sci., NS-23, No. 1 (February 1976).

D. W. Miller and M. S. Gerber, "The Technology for Load Management Rate Structures," Public Utilities Fortnightly, Vol. 97, No. 12, p. 41, June 3, 1976.

10. PRESENTATIONS AND ABSTRACTS:

D. W. Miller, P. A. Schlosser, M. S. Gerber, R. F. Redmond, and W. W. Hunter, Jr., "A Prototype Gamma Camera System Based on a Strip-Electrode, High Purity, Germanium Detector," presented at the 1974 Society of Nuclear Medicine Meeting, San Diego, California, June 1974.

P. A. Schlosser, M. S. Gerber, D. W. Miller, and A. H. Deutchman, "A Large Scale Medical Gamma Camera System Based on Orthogonal Strip, High Purity Germanium Detectors," IEEE Nuclear Symposium, December 1974.

D. W. Miller, P. A. Schlosser, M. S. Gerber, and A. H. Deutchman, "A Prototype Gamma Ray Camera for Nuclear Medicine Based on a High Purity Germanium Detector," 1975 Annual Meeting of the Ohio Academy of Science, April 1975.

M. S. Gerber and D. W. Miller, "Metering and Related Technical Aspects for Implementing Improved Electric Utility Rate Structures," workshop presented at the Public Utilities Commission of Ohio, November 1975.

P. A. Schlosser, D. W. Miller, M. S. Gerber, J. W. Steidley, A. S. Zolnay, and A. H. Deutchman, "A Prototype Gamma Ray Camera for Nuclear Medicine Based on a High Purity Germanium Detector," to be presented at the ERDA Symposium on X- and Gamma-Ray Sources and Applications, Ann Arbor, Michigan, May 19-21, 1976.

11. REPORTS AND THESES:

M. S. Gerber, "The Analysis and Development of Instrumentation for a Position Sensitive Semiconductor Gamma Ray Camera," unpublished Ph.D. dissertation, The Ohio State University, June 1975.

R. F. Redmond, W. W. Hunter, Jr., D. W. Miller, P. A. Schlosser,

M. S. Gerber, "To Develop a New Semiconductor Gamma Camera System for Nuclear Medicine," Final Report to The Department of Health, Education, and Welfare, National Institutes of Health, National Institute of Neurological Diseases and Stroke, June 1975.

D. W. Miller, M. S. Gerber, R. F. Redmond, G. C. Ficke, J. R. Rusick, and B. K. Utts, "Evaluation of Metering and Related Technical Aspects for Implementing Improved Electric Utility Rate Structures," Final Report to the Public Utilities Commission of Ohio, October 1975.

12. PATENT DISCLOSURES:

"A Method of Forming A Continuous, Charge-Splitting Resistive Layer on Grooved or Grooveless Orthogonal Strip Semiconductor Detectors," filed October 1975 with The Ohio State University College of Engineering (with P. A. Schlosser, D. W. Miller, A. S. Zolnay, and J. W. Steidley).

13. PATENT APPLICATIONS:

"Control System for Gamma Camera," Application Docket No. 2-086.

"Gamma Camera System with Composite Solid State Detector," Application Docket No. 2-087, with D. W. Miller.

"Gamma Camera System," Application Docket No. 3-089, with D. W. Miller.

14. CONSULTING EXPERIENCE:

Battelle Memorial Institute, Columbus, Ohio 1973-75 (X-ray Radiation Detection).

Physics International, San Leandro, California, 1973 (X-ray Radiation Detection).

Spacetac, Inc., Bedford, Massachusetts, 1975 (Instrumentation Design Analysis).

RESUME

NAME: Francis Alfred Kulacki
2206 Harwitch Road
Columbus, Ohio 43221
Office: (614) 422-6676

PRESENT POSITION:

Associate Professor
Department of Mechanical Engineering
The Ohio State University
206 West 18th Avenue
Columbus, Ohio 43210

PERSONAL: Born: [REDACTED]
Married: No
Health: Excellent
Social Security Number: [REDACTED]

EDUCATION:

1. Degrees

B.S. in Mechanical Engineering, June 1963
Illinois Institute of Technology
Chicago, Illinois 60616

M.Sc. in Gas Technology, June 1966
Illinois Institute of Technology
Chicago, Illinois 60616
(Adviser: Prof. Dimitri Gidaspow)

Ph.D. in Mechanical Engineering, December 1971
University of Minnesota
Minneapolis, Minnesota 55455
(Adviser: Prof. Richard J. Goldstein)

2. Extracurricular Activities in Undergraduate College

ASME
Technology News (Business Manager)
Varsity Tennis (Major Letter)
IIT Student Association Representative
Phi Kappa Sigma Fraternity (Vice President, Secretary, Steward)
Election Commission
Senior Class Treasurer
Beta Omega Nu (Inter-Greek Fraternity)

3. Honors, Awards, Scholarships

NSF Traineeship (University of Minnesota)
Stan Lensy Scholarship of the Kosciuszko Foundation
(University of Minnesota)
Institute of Gas Technology Fellowship (IIT)
Baltimore Gas and Electric Company Scholarship to IIT
Who's Who in American Colleges and Universities (1963)

MILITARY RECORD: None

PROFESSIONAL AND HONORARY SOCIETIES:

Tau Beta Pi
Pi Tau Sigma
Sigma Xi, Full Member (1975)
ASME - Associate Member (1964-1975), Full Member (1975 to
present)
Member Heat Transfer Division Committee K-8 Theory and
Fundamental Research
Faculty Adviser to OSU Student Section
Member Executive Committee of Columbus Section of ASME,
September 1974 - present
Treasurer, Columbus Section ASME, September 1975 - June 1976
ASEE
Texnikoi - Honorary Member, 1975

EMPLOYMENT HISTORY:

1. September 1971 to present

Position: Associate Professor (September 1975 to present)
Assistant Professor (September 1971 to August 1975)
Department of Mechanical Engineering
The Ohio State University

Responsible for teaching undergraduate courses in thermodynamics, fluid mechanics, and heat transfer and graduate courses in transport phenomena, turbulent flow and heat transfer, conduction heat transfer, and applied engineering mathematics. Have given courses at Wright Patterson AFB graduate extension campus.

2. September 1966 to August 1971

Position: Research Assistant and Teaching Associate
Department of Mechanical Engineering
Heat Transfer Laboratory
University of Minnesota
Minneapolis, Minnesota 55455

Conducted theoretical and experimental research on natural convection heat transfer. Experimental work involved Mach-Zehnder interferometry. Two years teaching undergraduate courses in thermodynamics (fundamentals and applications), heat transfer, one-dimensional gas dynamics, and design (senior level special projects course in the thermal sciences disciplines).

3. June 1966 to August 1966

Position: Temporary Engineer, summer
Institute of Gas Technology
3425 South State Street
Chicago, Illinois 60616

Assigned to Gas Air Conditioning Group. Responsible for design and construction of an experimental facility for drying schedule studies of anhydrous salts used in gas-fired air conditioning equipment.

4. August 1963 to June 1966

Position: Graduate Fellow and Research Assistant
Institute of Gas Technology
3424 South State Street
Chicago, Illinois 60616

Conducted experimental research on catalytic combustion of hydrogen and methane. Worked as assistant in the shock tube laboratory.

5. June 1964 to September 1966

Position: Counselor in Men's Residence Hall
Illinois Institute of Technology
Office of the Dean of Students
Technology Center
3300 South Federal
Chicago, Illinois 60616

Responsible for discipline, coordination of social activity, and liaison between students and administration for a dormitory of 105 students. A large percentage of the graduate students were from foreign countries; the others were freshmen and sophomores. I was aided by one assistant counselor.

6. 1960 to 1963 (summers)

Position: Junior Engineer, summer, Gas Division

Baltimore Gas and Electric Company
Lexington Building
Lexington and Liberty Streets
Baltimore, Maryland 21202

Assigned to Engineering, Service, Gas Manufacturing, and Construction departments of Gas Division. Major responsibility was to learn nature and scope of function of each department and to perform special projects designated by immediate supervisor. Special projects included heat transfer calculations combined with field measurements to determine steam losses on company steam services, development of an improved water syphon, odorant level testing on company gas distribution system, and study of gas meter maintenance practices.

7. January 1963

Position: Temporary Engineering Personnel
Illinois Institute of Technology Research Instruments
Cor-Plan Associates
Technology Center
10 West 35th Street
Chicago, Illinois 60616

Job function was writing of operating and maintenance manuals for gasoline-powered electrical equipment used in fall-out shelter equipment.

RESEARCH GRANTS AND CONTRACTS AT OSU:

1. Sigma Xi Grant in Aid of Research for Studies of Thermal Convection with Volumetric Energy Sources (1973, \$200).
2. "Application of Electrostatic Fields and Corona Wind in the Improvement of Baking Processes," OSU Engineering Experiment Station Project No. 439X, sponsor: Nabisco Corporation, funding: 3/73-6/74, \$38,133; 7/74-6/75, \$28,310.
3. "Studies of Heat Source Driven Natural Convection," OSU Research Foundation Project No. RF3746-A1, sponsor: NASA, Theoretical Studies Branch, Moffett Field, California (NGR 36-998-025), funding: 8/73-6/74, \$4,214; 8/74-7/75, \$4,500; 8/75-8/76, \$4,200.
4. "Steady and Transient Natural Convection in Enclosed Fluid Layers with Volumetric Energy Sources," OSU Research Foundation Project No. RF3952-A1, and RF4230-A1, sponsor: USAEC (AT(11-1)-2470), funding: 7/74-6/75, \$30,000; 7/75-7/76, \$35,000.

5. "Coupled Convective Momentum and Mass Transport from Porous Tubes in Crossflow," OSU Research Foundation Project No. RF3937-A1, sponsor: NSF (GK-43727), funding: 7/74-6/76, \$34,300.
6. "The Identification of Scientific Programs to Utilize the Space Environment," with R. M. Nerem, OSU Research Foundation Project No. RF4207-A1, sponsor: NASA, Langley Research Center (NGS1212), funding: July 1, 1975-June 30, 1976, \$22,848.
7. "Testing of Low Velocity Probes," OSU Engineering Experiment Station Project No. 5919, sponsor: Stilson Laboratories, Columbus, Ohio, funding: June, 1975, \$100.

PUBLICATIONS:

1. Theses

Catalytic Combustion in a Flat Rectangular Channel, MSc thesis, Illinois Institute of Technology, June 1966.

Thermal Convection in a Horizontal Fluid Layer with Uniform Volumetric Energy Sources, PhD thesis, University of Minnesota, December 1971.

2. Papers

1. Kulacki, F. A., and Gidaspo, D., "Convective Diffusion in a Parallel Plate Duct with One Catalytic Wall - Laminar Flow - First Order Reaction, Part II: Experimental," Canad. J. Chem. Engrg., 45, 74-78, April 1967.
2. Kulacki, F. A., Gidaspo, D., and Solbrig, C. W., "Analysis of Nth Order Reaction Rate Data Using Mixing Cup Charts," Proceedings, XXXVI Congress Internationale de Chime Industrielle, Brussels, September 10-21, 1966.
3. Kulacki, F. A., and Goldstein, R. J., "Thermal Convection in a Horizontal Fluid Layer with Uniform Volumetric Energy Sources," J. Fluid Mech., 55, 271, 1972.
4. Kulacki, F. A., and Goldstein, R. J., "Eddy Heat Transport in Thermal Convection with Volumetric Energy Sources," Paper NC 2.6, Proceedings, Fifth International Heat Transfer Conference, Tokyo, Japan, September 3-7, 1974.
5. Kulacki, F. A. and Goldstein, R. J., "Hydrodynamic Stability in Fluid Layers with Volumetric Energy Sources," Applied Sci. Res., 31, 81 (1975).

6. Kulacki, F. A., and Nagle, M. E., "Natural Convection in a Horizontal Fluid Layer with Volumetric Energy Sources," J. Heat Trans., 97C, 204-211, 1975.
 7. Reif, T. H., Nerem, R. M., and Kulacki, F. A., "An In Vitro Study of Transendothelial Albumin Transport in a Steady State Pipe Flow at High Shear Rates," Advances in Engineering, eds. J. A. Brighton and S. Goldstein, 160-161, ASME, New York, 1974.
 8. Kulacki, F. A., and Ramchandani, R., "Hydrodynamic Stability in a Porous Layer Saturated with a Heat Generating Fluid," Warme-Und Stoffubertragung, 8, 179-185 (1975).
 9. Reif, T. H., Nerem, R. M., and Kulacki, F. A., "An In Vitro Study of Transendothelial Albumin Transport in a Steady State Pipe Flow at High Shear Rates," to be published in J. Fluids Engng., 1975 (in press).
 10. Kulacki, F. A., Emara, A. A., and Min, J. H., "Natural Convection in Internally Heated Fluid Layers - PAHR Applications," Proceedings, Post Accident Heat Removal Information Exchange Meeting, Sandia Laboratories, Albuquerque, New Mexico, November 13-14, 1975.
 11. Kulacki, F. A., and Emara, A. A., "Heat Transfer Correlations for Use in PAHR Analysis and Design," Trans., American Nuclear Society, Vol. 22, pp. 447-448, November 1975.
 12. Baker, L., Faw, R. E., and Kulacki, F. A., "Post Accident Heat Removal I: Heat Transfer Within an Internally Heated Non-Boiling Liquid Layer," submitted to J. Nuc. Sci. Tech., November, 1975 (in process).
3. Technical Reports
1. Kulacki, F. A., Nagle, M. E., and Cassen, P., "Studies of Heat Source Driven Natural Convection," The Ohio State University Research Foundation, RF-3746, Technical Report 3746-1, July 1974.
 2. Kulacki, F. A., and Daubenmier, J. A., "Experiments on Coupled Heat and Mass Transfer in the Presence of an Electrostatic Field," The Ohio State University Engineering Experiment Station, Project EES 439X, Technical Report No. 1, July 1974.
 3. Kulacki, F. A., and Kevra, J. M., "Coupled Heat and Mass Transfer in the Presence of an Electrostatic Field," The Ohio State University Engineering Experiment Station,

Project EES 439X, Technical Report No. 2, July 1975.

4. Kulacki, F. A., and Emara, A. A., "High Rayleigh Number Free Convection in Enclosed Fluid Layers with Internal Heat Sources," The Ohio State University Research Foundation, RF-3746, Technical Report 3952-1, July, 1975; also published by the United States Nuclear Regulatory Commission, Report No. NUREG 75/065, July, 1975.
5. Kulacki, F. A., and Emara, A. A., "Studies of Heat Source Driven Natural Convection," The Ohio State University Research Foundation, RF-3746, Technical Report 3746-2, November, 1975.

PRESENTATIONS:

1. "An Aspect of Experimental Reactor Engineering," Chemical Engineering Department, Instituto Tecnológico y de Estudios Superiores de Monterrey, Monterrey, Nuevo Leon, Mexico, December 20, 1967.
2. Natural Convection in Horizontal Fluid Layers with Uniform Volumetric Energy Sources," Mechanical Engineering Seminar, The Ohio State University, November 1971.
3. Natural Convection with Volumetric Energy Sources: Stability and Energy Transport in Fluid Layers," NASA Space Sciences Division Seminar Series, Ames Research Center, Moffett Field, California, June 12, 1973.
4. "Natural Convection with Internal Energy Sources," Department of Aeronautical Engineering Seminar, The Ohio State University, February 1974.
5. "Studies of Natural Convection with Internal Energy Sources," Reactor Analysis and Safety Division Seminar, Argonne National Laboratory, Argonne, Illinois, March 14, 1974.
6. "Experiments on Natural Convection Heat Transfer in a Horizontal Fluid Layer with Volumetric Heat Sources," AIAA/ASME, Thermophysics and Heat Transfer Conference (open forum), Boston, Massachusetts, July 15-17, 1974.
7. "Steady and Unsteady Natural Convection with Volumetric Energy Sources," Fifth International Heat Transfer Conference (open forum), Tokyo, Japan, September 3-7, 1974.
8. "Natural Convection in a Horizontal Fluid Layer with Uniform Volumetric Energy Sources," (16 mm film, co-authored with R. J. Goldstein), Fifth International Heat Transfer Conference, Tokyo, Japan, September 3-7, 1974.

9. "Molten Core Heat Transfer Studies," Second Water Reactor Safety Information Meeting, USAEC, Germantown, Maryland, September 19-20, 1974.
10. "Heat Transfer in a Molten Core," Fast Reactor Information Exchange Meeting, Sandia Laboratories, Albuquerque, New Mexico, October 8-9, 1974.
11. "Natural Convection in Internally Heated Fluid Layers - PAHR Applications," United States Nuclear Regulatory Commission . Third Water Reactor Safety Meeting, Gaithersburgh, Maryland, September 29-30, 1975.
12. "Natural Convection in Internally Heated Fluid Layers - PAHR Applications," Post Accident Heat Removal Information Exchange Meeting, Sandia Laboratories, Albuquerque, New Mexico, November 13-14, 1975.
13. "Heat Transfer Correlations for Use in PAHR Analysis and Design," American Nuclear Society, Winter Meeting, San Francisco, California, November 21, 1975.
14. "Natural Convection with Internal Heating, A Review of Recent Results," Fluid Mechanics Division Seminar, Departments of Chemical, Civil, and Mechanical Engineering, University of Utah, Salt Lake City, Utah, November 20, 1975.

THESES ADVISED:

1. Natural Convection Energy Transfer in a Horizontal Fluid Layer with Volumetric Heat Sources, Michael E. Nagle, M.Sc., March 1974.
2. Thermal Instability in Porous Fluid Layers Heated from Within, Ramesh Ramchandani, M.Sc., March 1974.
3. Experiments on Coupled Heat and Mass Transfer in the Presence of an Electrostatic Field, John A. Daubenmier, M.Sc., June 1974.
4. An in Vitro Study of Transendothelial Transport of 131I-Albumin in Canine Common Carotid Arteries at High Shear Rates, Thomas H. Reif, M.Sc., June 1974 (co-advised with Professor R. M. Nerem).
5. Coupled Heat and Mass Transfer in the Presence of a Point Source Electric Field, James M. Kerva, M.Sc., June 1975.
6. Design and Construction of a Low Speed Wind Tunnel and Preliminary Study of Flow About a Porous Tube with Blowing, Eugene C. McCall, M.Sc., November, 1975.

CONSULTING:

1. Battelle Memorial Institute, Columbus, Ohio, (1973 to present)
- heat transfer.
2. Anchor Hocking Corporation, Lancaster, Ohio, (1973 to present)
- heat transfer, fluid flow, and electrofluidmechanics.
3. Precision Latex Company, Inc., Cardington, Ohio, (Fall 1973) -
heat transfer.
4. General Motors Corporation, Technical Center, Warren, Michigan
(Fall 1973) - electrofluidmechanics and catalytic combustion.
5. Argonne National Laboratory, Argonne, Illinois, (October 1974
to present) - heat transfer related to the post-accident heat
removal problem in nuclear reactors.

OTHER ACTIVITIES:

1. Chapter adviser of Alpha Chi Chapter of Phi Kappa Sigma fraternity at OSU, 1973 to present.
2. Department of Mechanical Engineering faculty committees:
Display Committee (1971-1973)
Special Events (1972-1973)
Graduate Committee (1971-1974)
Departmental Planning (1973-1976, Chairman 1974-1976)
Curriculum - undergraduate options (1973-1974)
Laboratory Development (1974-1976)
3. College of Engineering committees:
Atmospheric Sciences Program (1973 to present)
Advisory Committee on Reactor Operations (1974 to present)
4. University committees:
University Calendar (1975 to present)
Graduate Student Research Recognition Award Committee,
Graduate School, 1975
5. OSU University Senate Alternate, 2 years beginning September,
1974
6. Journal articles reviewed for:
Applied Mechanics Reviews (1973 to present)
Journal of Heat Transfer (1973 to present)
AIChE Journal (1972)

PROFESSIONAL RESUME

1. NAME: PHONE:

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2. PRESENT POSITION:

Assistant Professor of Nuclear Engineering, Department of
Mechanical Engineering, The Ohio State University, Columbus,
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3. PERSONAL:

Born: [REDACTED]
Married: Kathleen
Social Security Number: [REDACTED]
4. DEGREES:

BS - Engineering Physics, The Ohio State University, 1965
MS - Nuclear Engineering, The Ohio State University, 1967
PhD - Nuclear Engineering, The Ohio State University, 1972
5. HONORS:

American Nuclear Society, Special Services Award, 1969
The Ohio State University, Nuclear Engineering Distinguished
Service Award, 1971
6. PROFESSIONAL EXPERIENCE:

Teaching Assistant, The Ohio State University, Department of
Mathematics, 1962-1963. Taught recitation sections in freshman
mathematics.

Associate Engineer, Western Electric Company, Columbus labora-
tories, summers 1963, 1964, and 1965. Developed testing and
production methods for Electronic Telephone Switching Systems.

Research Laboratory Assistant, The Ohio State University, Depart-
ment of Physics, 1964-65. Developed instrumentation for
spectroscopy experiments using semi-conductor radiation detectors
in the Low Energy Nuclear Physics Laboratory.

Graduate Teaching Assistant, The Ohio State University, Depart-
ment of Physics, 1966. Taught recitation sections in classical
mechanics and modern physics.

Physicist, Industrial Nucleonics Corporation, Columbus, Ohio, summer, 1966. Participated in federally funded research projects involving the development of nuclear instrumentation.

Research Associate, 1966-70, and Teaching Associate, 1970-72, The Ohio State University, Department of Mechanical Engineering, Nuclear Engineering Section. Participated in research contracts for the development of ferroelectric radiation detectors and imaging systems. Performed theoretical, experimental and computer studies of the behavior of solid state and dielectric devices in radiation environments. Developed computer codes for the analysis and unfolding of radiation spectra. Developed methods for the application of advanced electronic techniques to problems involving radiation detection and imaging. Taught courses in Thermodynamics (ME 301), Heat Transfer and Fluid Flow (ME 311), Mechanical Engineering Measurements (ME 570), Mechanical Engineering Laboratory (ME 581), and Basic Nuclear Science and Engineering (NE 505). Participated in NSF Summer High School Training Program and lectured in an Ohio State University Short Course on Radioisotope Applications. Wrote proposals and reports to various industrial and governmental agencies. Served on several departmental committees.

Assistant Professor, 1973-present, The Ohio State University, Department of Mechanical Engineering, Nuclear Engineering Section. Member of the Graduate Faculty. Taught courses in Nuclear Science and Engineering, Mechanical Engineering Laboratory and Engineering Graphics. Wrote proposals to governmental agencies and industry. Advised and co-advised graduate students in masters thesis research. Supervised federally funded research contracts. Served on Mechanical Engineering Research Committee (Chairman, 1973-1974), Publicity Committee, Nuclear Engineering Graduate and Curriculum Committees, and College of Engineering Irregular Students Committee.

7. CONTRACT RESEARCH:

Research Associate, "Development of Ferroelectric and Ferromagnetic Radiation Detectors," July 1966-June 1970 (\$100,000). Sponsor: U. S. Army Nuclear Effects Laboratory, Department of Defense.

Research Associate, "Development of Ferroelectric Radiation Detectors and Imaging Devices," September 1970-August 1971 (\$8,000). Sponsor: The Ohio State University Engineering Experiment Station.

Co-Principal Investigator and Project Supervisor, "Development of Pyroelectric Field Effect Detectors, June 1973-March 1975 (\$25,000). Sponsor: Advanced Research Projects Agency and U.S.

Army Night Vision Laboratory, Department of Defense.

Co-Principal Investigator and Project Supervisor, "To Develop a Semiconductor Gamma Camera System for Nuclear Medicine," July 1972-December 1974 (\$300,000). Sponsor: National Institute of Health, Department of Health, Education and Welfare.

Co-Principal Investigator and Project Supervisor, "Development of a Germanium Gamma Ray Camera System for Nuclear Medicine," October 1975-September 1978 (\$513,000). Sponsor: Picker Corporation, Nuclear and Ultrasound Division.

8. PROFESSIONAL AND SCIENTIFIC ORGANIZATIONS:

American Nuclear Society, 1966-
Southwestern Ohio Section of the American Nuclear Society, 1972-
Institute of Electrical and Electronic Engineers, 1972-
Society of Nuclear Medicine, 1975-

9. PATENT DISCLOSURES:

"Flat-Panel Solid State Radiation Imaging Systems Which Employ Ferroelectric Sensor Arrays and Operate in the Real-Time Mode," filed October 1970 with The Ohio State University Engineering Experiment Station.

"Developments Relating to an Improved Gamma Ray Camera System for Nuclear Medicine Based on Orthogonal Strip Germanium Detectors with Charge Splitting Signal Readout," filed September 1975 with The Ohio State University Research Foundation.

10. PUBLICATIONS AND PRESENTATIONS:

J. W. Steidley, D. W. Miller, M. S. Gerber, A. H. Deutchman, and P. A. Schlosser, "The Spatial Frequency Response of Orthogonal Strip Detectors, accepted for presentation at the 1975 IEEE Nuclear Science Symposium, San Francisco, November 1975; to be published in IEEE Trans. Nuc. Sci., Vol. NS-23, February 1976.

P. A. Schlosser, M. S. Gerber, D. W. Miller, and A. H. Deutchman, "A Large Scale Medical Gamma Camera System Based on Orthogonal Strip, High Purity Germanium Detectors," presented at the 1974 IEEE Nuclear Science Symposium, Washington, D.C., December 1974.

D. W. Miller, P. A. Schlosser, M. S. Gerber, R. F. Redmond, and W. W. Hunter, Jr., "A Prototype Gamma Camera System Based on a Strip-Electrode, High Purity Germanium Detector," presented at Annual Meeting of the Society of Nuclear Medicine, San Diego, June 1974.

P. A. Schlosser, D. W. Miller, M. S. Gerber, R. F. Redmond, J.W. Harpster, W. J. Collins, and W. W. Hunter, Jr., "A Practical Gamma-Ray Camera System Using High-Purity Germanium," presented at the 1973 IEEE Nuclear Science Symposium, San Francisco, November 1973; also published in IEEE Trans. on Nuc. Sci., Vol. NS-21, No. 1, February 1974.

P. A. Schlosser, "Investigation of the Radiation Imaging Properties of Pyroelectric Detector Arrays," Ph.D. Dissertation, The Ohio State University, December 1972.

P. A. Schlosser and D. D. Glower, "A Self-Scanned Ferroelectric Image Sensor," IEEE Trans. on Sonics and Ultrasonics, Vol. Su-19, No. 2, pp. 257-262, April 1972. Presented at the 1971 IEEE Symposium on Applications of Ferroelectrics, Yorktown, New York. Also published in Ferroelectrics, Vol. 3, N. 2, pp. 257-262, February 1972.

P. A. Schlosser and D. D. Glower, "Development of Ferroelectric Nuclear Radiation Detectors," Final Report to the U. S. Army Nuclear Effects Laboratory, Contract No. DA-18-035-AMC-952(A), April 1971.

P. A. Schlosser, "The Use of Ferroelectric Materials in Radiation Dosimetry," presented at the Annual Meeting of the American Society for Testing Materials, June 1970, Toronto. (Invited).

P. A. Schlosser, D. W. Miller and D. D. Glower, "The Theory and Application of Ferroelectric Radiation Detectors," Int. J. of Nondestructive Testing, Vol. 2, pp. 19-20, 1970.

P. A. Schlosser, "Ferroelectric Radiation Detectors," presented at the Ninth Symposium on Physics and Nondestructive Testing, September 1969, Chicago, sponsored by Gordon and Breach Science Publishers. (Invited).

D. D. Glower, D. W. Miller, and P. A. Schlosser, "Development of Ferroelectric Nuclear Radiation Detectors," Interim report to the U. S. Army Nuclear Defense Laboratory, AD-671610, June 1968.

D. W. Miller, P. A. Schlosser, J. Burt, D. D. Glower, and J. H. McNeilly, "A Pulsed Radiation Energy Spectrometer Using Ferroelectrics," IEEE Trans. on Nuclear Sci., Vol. NS-14, pp. 245-251, December 1967.

P. A. Schlosser, "An Iterative Unfolding Method for the Measurement of Pulsed Radiation Spectra," MSc Thesis, The Ohio State University, June 1967.

11. SPECIAL PROFESSIONAL ACTIVITIES:

Arrangements Committee, IEEE Annual Conference on Nuclear and Space Radiation Effects, at The Ohio State University, June 1967.

Arrangements Chairman, Midwest Student American Nuclear Society Conference, The Ohio State University, May 1969.

Arrangements Chairman, American Nuclear Society Topical Meeting on Nondestructive Testing in the Nuclear Power Industry, at The Ohio State University, September 1975.

Treasurer, American Nuclear Society OSU Student Chapter, 1969-71.

Advisor, NSF High School Summer Training Program (1971-73).

Faculty Advisor, Theta Chi Fraternity, 1972- .

Treasurer, The Ohio State University Alumni Intrafraternity Council, 1972-74.

Speaker on Engineering Careers at several high schools, 1973-75.

12. CONSULTING EXPERIENCE:

Battelle Memorial Institute, Columbus, Ohio 1973-75 (X-ray Radiation Detection)

Physics International, San Leandro, California, 1973 (X-ray Radiation Detection)

The Picker Corporation, North Haven, Connecticut, 1975-1976 (Gamma Ray Camera Development)

Spacetac, Inc., Bedford, Massachusetts, 1975 (Nuclear Space Instrumentation Design Analysis)

Canberra Industries, Meriden, Connecticut, 1975 (High Purity Germanium Detectors)

B. Growth, Morphogenesis and Metabolism of Plant
Embryos in the Zero-Gravity Environment

by

Dr. V. Raghavan
Department of Botany
Telephone: (614) 422-4723

EXPERIMENT TITLE: Growth, Morphogenesis and Metabolism of Plant Embryos in the Zero-Gravity Environment

EXPERIMENTER: Valayamghat Raghavan, Associate Professor of Botany

The Ohio State University
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TECHNICAL ABSTRACT:

The goal of this proposal is to devise a candidate experiment using a system from flowering plants that would be suitable to be carried in the space in the unmanned long flight of the LDEF. In preliminary experiments, the potential use of aseptically cultured plant embryos for studies relating to the effect of zero-gravity environment of the space was evaluated. Effect of the space environment on the growth and development of embryos will be monitored by fixing samples at timed intervals and analyzing them for the rate of cell division, cell expansion and differentiation of tissues and organs. Comparison of RNA and protein contents of whole cells and subcellular fractions of cells of embryos grown in the laboratory and in the space environment will be made to determine the effect of zero-gravity on macromolecule synthesis during embryogenesis.

BENEFITS:

Thus far no work has been carried out to determine the effect of weightlessness, gamma radiation or other stresses of the space environment on fundamental biochemical processes of plant cells, especially those concerned with cell growth and division. The data from the proposed experiments will provide meaningful information on plant growth beginning with the very embryonic stages, as far as it relates to the gravity free environment of the space. Since the embryo is the organ of the seed which initiates growth processes in a new habitat, results of these experiments will have potential implication in the introduction and survival of plants in space. If the space environment induces mutations in the embryogenic cells, mutants of commercial significance with desirable attributes may be obtained.

1.0 TECHNICAL DISCUSSION OF EXPERIMENT APPROACH, OBJECTIVES, JUSTIFICATION, AND BENEFITS.

Previous space flight experiments have examined the effect of the space environment on several forms of plant life, including callus tissues originating from different plants. These experiments have shown no significant differences in growth from ground controls or only slightly enhanced growth when sample measurements such as length and diameter of the root and stems or fresh and dry weight of the tissues were made. However, the need for more definitive experiments relating

to the effect of the space environment on growth, organization, differentiation and macromolecular synthesis in plants is obvious if the possible biological responses of plants could be exploited in later flights.

With this in mind, it is proposed to develop a candidate experiment to be performed on the LDEF using embryos of a flowering plant. The embryo is the master unit of the seed from which the future sporophyte is formed. Even in an immature seed, the embryo is sufficiently well developed with morphologically differentiated primordia of the future vegetative organs of the plant, namely, the radicle or the embryonic root and the epicotyl or the embryonic stem which in many cases may have already the rudiments of the first pair of leaves. It is clear that many of the essential properties of interactions seen in the adult plant can be observed in the embryos which provide a much simpler system to work with in the restricted space available in the LDEF. Moreover, since the embryo grows relatively slowly within the confines of the culture tube to become an adult plant, this experiment could take full advantage of the long term LDEF conditions.

Growth of embryos in culture provides easily observable and assessable manifestations of growth and metabolic activity. Examples are: rapid cell division during early phase of growth; differentiation of tissues (vascular system) and organs (leaf, root, stem) during progressive embryonic development; increase in dry weight, protein and RNA contents (Raghavan, 1966; Walbot, Clutter and Sussex, 1972; Walbot et al., 1972).

Several properties of the environment such as zero-gravity, magnetic field, altered geophysical periodicity, radiation and vacuum are frequently considered unique. In the present proposal, zero gravity was selected to capitalize on the advantage of the long duration of the flight of LDEF. Moreover, effect of gravity on plant growth is seen in the dramatic curvature of roots and other underground organs towards gravity and of stems and other aerial organs away from gravity. Preliminary experiments have also suggested that development of embryos will be affected in zero gravity and as a consequence, cellular and metabolic activity will also be changed by the lack of sedimentation. It is not known whether this is a direct effect of zero-gravity or due to the effect of weightlessness on the energy transport processes in the cell.

Preliminary experiments have led to the selection of excised and aseptically cultured embryos of the common garden pea (Pisum sativum Alaska) for Candidate experiment in the LDEF. Criteria applied for the selection of pea embryos as test organism are: (i) have high probability of being sensitive to the parameter of the space environment being tested, (ii) are relatively easy to grow large number of embryos under aseptic conditions, (iii) show a regular pattern of growth and morphogenesis in culture, (iv) medium requirements are simple and, (v) growth in culture is slow and is unaccompanied by "precocious germination."

A thorough literature search has revealed that no studies have been conducted to determine how zero gravity affects cellular aspects of growth of plant embryos and important macromolecular synthetic processes such as protein and RNA synthesis. The scope of this proposal will therefore involve four basic tasks: (i) determine how zero gravity could affect cell division, cell expansion and morphogenesis of embryos, (ii) determine the effect of zero gravity environment on the vascular tissue differentiation in the shoot and root primordia of the embryos, (iii) determine how zero gravity could affect system functions especially those concerned with RNA and protein synthesis, (iv) determine how zero gravity could affect the distribution of RNA and protein in the subcellular fractions of cells of the embryo. Experimental details are presented in Appendix A.

Applications:

Data on the growth of cultured embryos and their metabolism in the zero gravity environment of the space for prolonged periods will open up the problems involved in the introduction and survival of plants in space. The types of problems that are significant in this respect are,

1. Seed germination - Germination of the seed is the visible and outward manifestation of growth of an embryo enclosed in the seed. Embryo culture is probably one of the best means to evaluate the potential success in initiating growth processes in seeds of important crop plants in the space.
2. Increased food production - Some of the parameters of the space will probably result in an increase in overall reaction rates and possibly in increased protein accumulation. This will have significance in plants grown primarily for food.
3. Assessment of mutant embryos - Mutations affecting specific organs of the embryo during prolonged weightlessness in space might yield commercially useful clones, through tissue culture techniques.
4. Potential for expanded experiments - These experiments will be potentially useful for planning more elaborate experiments on the growth and metabolism of plant embryos in the zero gravity environment. The present proposed study will establish scientific and technical bases for conducting future experiments on either unmanned or manned satellites.

2.0 DISCUSS RELATED WORK AND EXPERIENCE.

This proposal is the result of my long-standing interest in applying anatomical, physiological, and biochemical techniques to study problems in plant development. Since the space environment might basically affect the normal development of the plant, I feel that these techniques could be profitably applied to analyze the effect of the

space stress on plant development. My previous work related to this project includes quantitative analysis of vascular tissue differentiation in a photo-induced bud (Jacobs and Raghavan, 1962), culture of small plant embryos (Raghavan, 1966 for review), RNA and protein metabolism in fern gametophytes (DeMaggio and Raghavan, 1973, for review) and induction of haploid embryoids anther culture (Raghavan, 1975, 1976).

My significant accomplishments in research are: (i) demonstration that even isolated apical buds of a photoperiodically sensitive plant can be induced to flower in a test tube (Raghavan and Jacobs, 1961; Raghavan, 1961), (ii) demonstration of the culture of very small embryos of Shepherds' purse by a balanced mixture of an auxin, cytokinin and a purine (Raghavan and Torrey, 1963), (iii) demonstration of the activation of nitrate reduction in orchid embryos (Raghavan and Torrey, 1964), (iv) demonstration of the role of RNA and protein synthesis in the transition of filamentous gametophyte to biplanar form (DeMaggio and Raghavan, 1973), (v) demonstration of phytochrome control of germination in fern spores (Raghavan, 1970a, 1973) and the role of performed RNA in the process (Raghavan, 1970b), (vi) demonstration of a new pathway involving the generative cell in androgenesis (Raghavan, 1976). I have an application for research support pending with the NSF, and an on-growing grant from the American Orchid Society for "Induction of Haploid Plants in Orchids."

References listed here are cited in full in Appendix C. Recent journal articles:

1. V. Raghavan, 1974. Control of differentiation in the fern gametophyte. American Scientist 62: 465-475.
2. V. Raghavan, 1976. Role of the generative cell in Androgenesis in henbane. Science 191: 388-389.

3.0 EXPERIMENT FACTS.

3.1 What specific space properties will it make use of?

Effect of zero-gravity environment

3.2 What is the preferred location on LDEF?

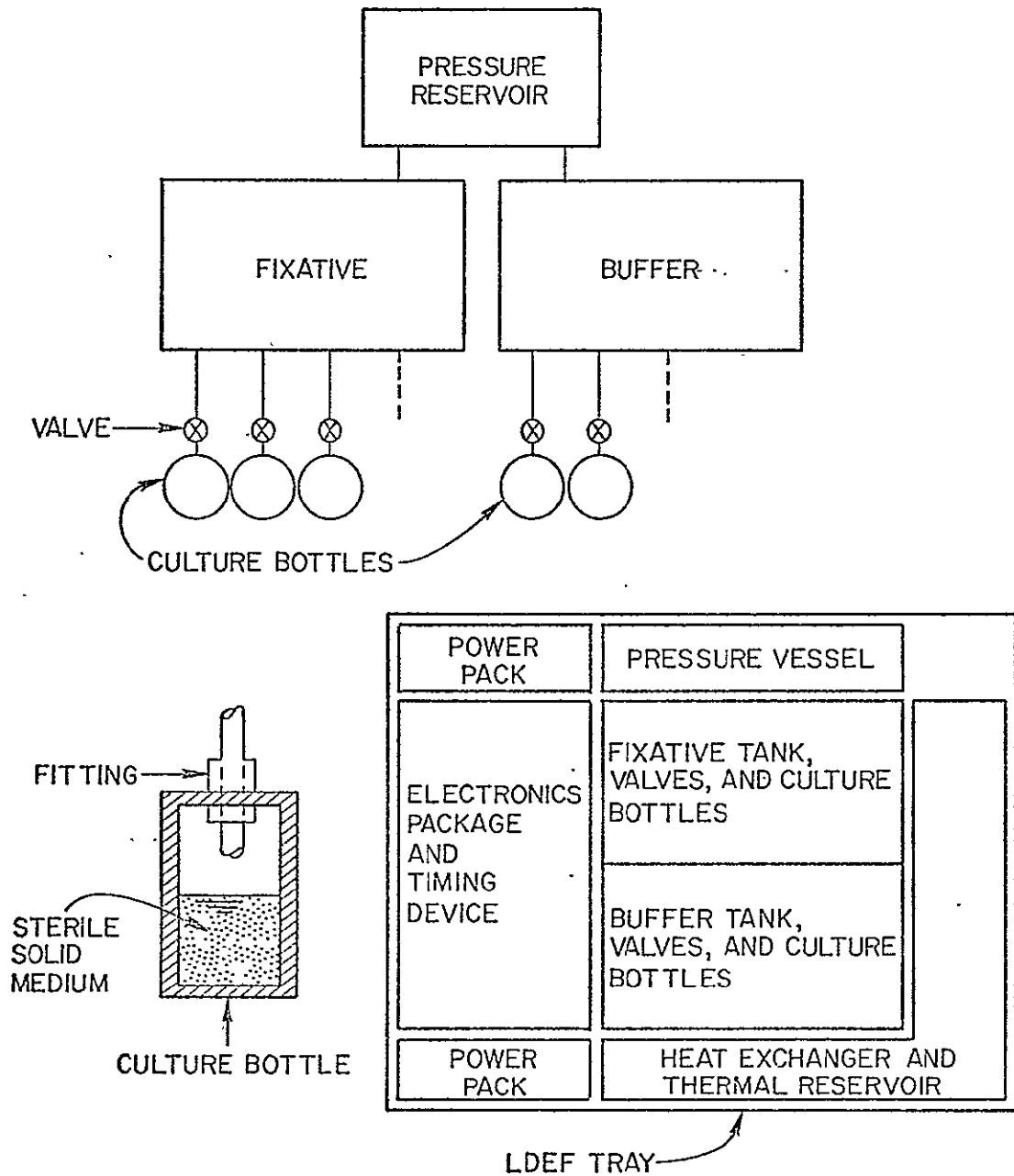
Leading side	<u> X </u>	Space end	<u> </u>
Trailing side	<u> </u>	Interior	<u> </u>
Earth end	<u> </u>		

3.3 What are the environmental constraints on the experiment?

- 3.3.1 Temperature range: - Temperature control is not critical. Temperature around experimental organisms should not normally exceed $25^{\circ}\text{C} \pm 10^{\circ}\text{C}$
- 3.3.2 Vibration and shock (pre- and post-launch and orbit):- Should be protected from excessive shock or vibration
- 3.3.3 Attitude control: - None
- 3.3.4 Radiation (particles and electromagnetic): - To be protected from particulate radiation
- 3.3.5 Vacuum (space): - None
- 3.3.6 Atmosphere (pre-, during, and post-launch and return): - None
- 3.3.7 Magnetic field: - None
- 3.4 What special protection must be provided to protect the experiment from the earth and space environments?

Cooling must allow for heating during lift off and reentry.
- 3.5 Physical description.
 - 3.5.1 Mass - 200 lb.
 - 3.5.2 Volume - 9 cu. ft.
 - 3.5.3 Surface area required - 36" X 36"

3.6 Sketch of Experimental Layout



4.0 EXPERIMENT HARDWARE

The experimental hardware incorporates the following features: In the experiment to explore zero-g effects on embryo growth as described, the basic unit is a French Square bottle, 1-2 oz. capacity, partially filled with an agar-solidified nutrient medium. Approximately 24 culture bottles of 100 cc each will be mounted on a shock proof tray which slides into the LDEF tray. Estimated collection of data in these are daily during the first 7 days and monthly thereafter. Twelve bottles will be for acetic alcohol and twelve for buffer solution. Collection of embryos in the acetic alcohol and in buffer solution will be affected by a system of small valves which will be either mechanically activated or electrically activated using a battery. Each valve will be activated only once to deliver solutions to the culture bottles. A timing mechanism will provide preprogrammed control of valve operations.

Hardware which must be developed includes the plumbing, valves, shock proof tray, tanks for holding the pressurized acetic alcohol and buffer solution, culture bottle mountings, programming devices and associated electronics, a suitable battery matched to the electro/mechanical requirements of the sample collection system, and a passive heat sink to diminish temperature variations in the culture bottles.

5.0 RESEARCH REQUIRED TO DEVELOP EXPERIMENT

Although methods proposed for determination of RNA and protein contents are generally suitable for plant tissues, further research is required to assess its suitability for the test organism. Similarly, subcellular fractionation methods are to be standardized to reduce cross contamination of the fractions.

6.0 SPECIAL FACILITIES REQUIRED FOR DEVELOPMENT AND ANALYSIS

My laboratory is equipped to undertake the biological experiments proposed. I have a transfer room for transfer of tissues aseptically, culture room, dark room, etc. A well equipped laboratory for biochemical and histochemical work is also available. However, an ultracentrifuge (Beckman Model L) necessary for a major part of the study is to be purchased.

7.0 COST ESTIMATE (Manpower)

7.1	Manpower (man-months and dollars)	mm	\$
7.1.1	Experiment design	33	65,792
7.1.2	Development of implementation plan	15	29,345
7.1.3	Ground-based testing	33	69,916
7.1.4	Pre-launch (analysis)	8	15,212
7.1.5	During mission	11	24,902
7.1.6	Post-launch (analysis)	31	61,611
7.2	Hardware (dollars)		
7.2.1	Engineering prototype		50,000
7.2.2	Hardware fabrication		25,000
7.2.3	Pre- and post-launch		20,000
7.3	Other direct costs (computer, travel, etc.)		15,750
7.4	Total costs		
7.4.1	Manpower	131	266,778
7.4.2	Hardware		95,000
7.4.3	Other Direct Costs		15,750
7.4.4	Total		377,528

8.0 SAFETY CONSIDERATIONS

No potential hazard to ground and flight personnel, spacecraft and other experiments are expected.

9.0 INTERACTIONS WITH SPACECRAFT AND OTHER EXPERIMENTS

Since the proposed experiment is a self-contained unit in itself, no interactions with spacecraft and other experiments are expected. Heat exchange, evolution of gases and other interferences are nil.

10.0 SCHEDULE

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CALENDAR YEARS

MILESTONES		1975			1976			1977			1978			1979			1980			1981		
1	Development				October 1976	<					>	April 1978										
2	Flight package											May 1978	<	>	June 1979							
3	Transfer to LDEF														June 1979 to	Sep. 1979						
4	Flight ground control														Sep. 1979	<	>	March 1980				
5	Analysis of data																	April 1980	<	>	June 1981	
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NOTES :

APPENDIX A -- Technical Discussion

The following experimental methods will be used for the research proposed in 1.0

1. Excision of embryos. Seeds of Alaska pea are soaked overnight in running tap water and sterilized in 12% commercial clorox for 5 min. They are washed repeatedly in sterile distilled water. Embryo axes are excised from seeds by gently splitting them open with a single-edged blade, and separating the two cotyledons. Embryo axis is seen attached to one of the cotyledons and can be easily separated and transferred to a culture medium. The whole operation takes less than a minute, and embryos from several hundred seeds can be excised and cultured in a day.
2. Medium. Medium used in this work will consist of macronutrient salts, trace elements vitamins and sucrose in proportions used by Raghavan and Torrey (1963). It is solidified by 0.9% agar. To prevent precocious germination of embryos, the medium is supplemented with 0.6 M mannitol. Embryo isolation will be undertaken 24 hours before they are shipped to the LDEF facility.
3. Flight Experiment. The following procedures will be followed for the flight experiment. Ground controls will be conducted simultaneously with the flight experiment.
 - a. Cultures will be fixed in acetic alcohol at intervals of 24 hr during the first 7 days of the flight and at intervals of 1 week thereafter. These materials will be used for analysis of cell division, cell expansion, vascular tissue differentiation and pattern of organ initiation upon arrival.
 - b. Cultures will be collected in a buffer at intervals of 24 hr during the first 7 days of the flight and at intervals of 1 month thereafter. The buffer will contain ingredients which will terminate the metabolic activity of the embryo at the time of collection. These materials will be used for analysis of RNA and protein contents in whole cells and subcellular fractions of cells.
4. Methods proposed to be used to analyze the effect of the space environment on growth and development of embryos are as follows:
 - a. The number of cells formed in the shoot meristem and root meristem will be determined separately by means of a maceration technique. Segments of identical lengths from

ground control and space flight are placed in ca 1 ml of a solution containing 5% HCl and 5% chromic acid for 24 hr. The fluid is then drawn repeatedly into a hypodermic syringe equipped with a No. 18 needle. The number of cells in aliquots of the homogenate is determined in a haemocytometer (Fosket, 1968).

- b. To determine the effect of the space environment on cell elongation, root segments from ground control and space flight are processed for microtomy by paraffin embedding techniques (Johansen, 1940). Lengths of cells from the epidermis, cortex, and ground meristem are measured with an ocular from median longitudinal sections of the root. Numerical data are analyzed statistically.
- c. Vascular tissue differentiation is followed in serial transverse sections of root tips and stem tips. Particular attention will be paid to the occurrence of the first xylem and phloem elements as the roots and stems elongate in laboratory culture or in culture in the space environment. Techniques developed by Jacobs and Morrow (1957) and Jacobs and Raghavan (1962) will be followed.
- d. Protein and RNA contents of embryos will be determined as follows: Samples kept in buffer are homogenized for 2 min in a Ten-Broeck glass homogenizer fitted with a power-driven pestle in 0.3 M sucrose containing 0.002 M Tris HCl buffer at pH 7.4 and 0.001 M CaCl_2 . The homogenate is cleared off cellular debris by filtering through a layer of cotton towel previously wetted with the medium. The homogenate is subjected to differential centrifugation to separate subcellular organelles. The arbitrary operational designations of cytoplasmic particulates, with the respective centrifugal force and times to be used are nuclei rich (700 g for 1 minute), chloroplast-rich (2000 g for 15 min), mitochondria-rich (22000 g for 20 min) (all in Sorval SS-3 centrifuge), ribosome-rich (100,000 g for 120 min in the Swinging-bucket type SW39 L rotor of Beckman L ultracentrifuge) and soluble supernatant fraction (after separation of the ribosome pellet).

RNA content, is determined by a modification of the method of Smillie and Krotkov (1960). The homogenate and subcellular fractions are treated with methanol and centrifuged to save the pellet. The pellet is then successively extracted for 3 min each once with methanol, containing 0.02 M formic acid, twice with 0.2 N perchloric acid and twice with water. After each extraction, the suspension is centrifuged for about 2 min at 1000 g in a

clinical centrifuge and the supernatant decanted off before adding the next solvent. The washed pellet is twice extracted with 2:2:1 ethanol: ether: chloroform mixture at 37°C for 30 min each to remove lipids. The supernatant is made 0.2 N with respect to perchloric acid, thoroughly mixed and centrifuged. The pellet is successively resuspended in 0.2N perchloric acid, water (2 changes), methanol, and methanol containing formic acid before extraction with lipid solvent. RNA is hydrolyzed from the lipid free pellet with 0.3 N KOH at 37°C for 24 hr. After extraction the mixture is chilled and enough perchloric acid added to give a concentration of 0.3 N followed by centrifugation to remove the precipitate. The RNA content of the extract is determined by referring absorbancy differences at 260 and 290 nm to a standard curve prepared with yeast RNA. RNA content of the debris free homogenate is total RNA.

For analysis of proteins, the homogenate and fractions are diluted to 2 ml with distilled water and proteins precipitated with an equal volume of cold trichloroacetic acid (TCA). The precipitate is sedimented by centrifugation at 1000 g for 5 min. The pellet is resuspended in 2 ml of fresh TCA, centrifuged and the sediment dissolved in 0.1 N NaOH. Aliquots are analyzed for protein by the method of Lowry et al. (1951) using Folin-phenol reagent with crystalline bovine serum albumin as the standard. The protein content of the debris-free homogenate is designated as 'total protein.'

References

1. D. E. Fosket, Proc. Natl. Acad. Sci. U.S. 1968; 59: 1089-1096.
2. W. P. Jacobs and I. W. Morrow, Amer. J. Bot. 1957, 44: 823-842.
3. W. P. Jacobs and V. Raghavan, Phytomorphology 1962, 12: 144-167.
4. D. A. Johansen, Plant Microtechnique, 1940.
5. O. H. Lowry, N. J. Rosebrough, A. L. Farr, and R. J. Randall, J. Biol. Chem. 1957, 193: 265-275.
6. V. Raghavan, Biol. Rev. 1966, 41: 1-58.
7. V. Raghavan and J. G. Torrey, Amer. J. Bot. 1963, 50: 540-551.
8. R. M. Smillie and G. Krotkov, Canad. J. Bot. 1960, 38: 31-39.
9. V. Walbot, T. Brady, M. E. Clutter, and I. M. Sussex, Develop.

Biol. 1972, 29: 104-111.

10. V. Walbot, M. E. Clutter, and I. M. Sussex, *Phytomorphology* 1972, 22: 59-68.

APPENDIX B --- Description of the Proposed Equipment

The major features of the apparatus sketched in the figures of item 3.6 include:

1. An overhead tank of acetic alcohol (fixative) connected to the culture bottles by separate solenoid valves
2. Activation and timing device to deliver fixative to the culture bottles during flight
3. Temperature control to keep the experimental system at approximately $25^{\circ} \pm 10^{\circ}\text{C}$
4. Light during 12 hours daily.

The experimental design to collect samples in buffer will also include the above features.

APPENDIX - C

BIOGRAPHICAL DATA

Name: Valayamghat Raghavan, Principal Investigator
Place & Date of Birth: [REDACTED]
Marital Status: Married, one child
Citizenship: Indian citizen
Status with U.S. Immigration & Naturalization Service: Immigrant

Education:

Maharaja's College, Ernakulam, India, B.S. 1950
Benares Hindu University, Benares, India, M.S. 1952
Princeton University, Princeton, New Jersey, Ph.D. 1961 (Thesis: Floral Histogenesis and Physiology of Perilla; advisor: William P. Jacobs)

Professional Experience:

1952-57. Research Fellow, Gauhati University, India
1957-58. Assistant Editor, Council of Scientific and Industrial Research, New Delhi, India
1961-63. Research Associate, Harvard University, Cambridge, Mass.
1963-70. Lecturer/Reader, University of Malaya, Kuala Lumpur, Malaysia
1966-67. Guest Investigator, Rockefeller University, New York
1970. Visiting Investigator, Dartmouth College, Hanover, N.H.
Present: Associate Professor, Department of Botany, The Ohio State University, Columbus, Ohio

Membership:

Botanical Society of America, American Society of Plant Physiologists, International Society of Plant Morphologists.

PUBLICATIONS

1. V. Raghavan & K. N. Murthy. 1954. Occurrence of bisexual flowers in an arecanut palm. *Science & Culture* 20: 239.
2. V. Raghavan & H. K. Baruah. 1956. On factors influencing fruit-set and sterility in arecanut (Areca catechu Linn.). I. Studies on pollen grains. *Journal of the Indian Botanical Society* 35: 139-151.
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4. V. Raghavan & H. K. Baruah. 1956. On factors influencing fruit-set and sterility in arecanut (Areca catechu Linn.). II. Germination of pollen grains and growth of pollen tubes under the influence of certain auxins, vitamins and trace elements. *Phyton* 7: 77-88.

5. V. Raghavan & H. K. Baruah. 1956. On arecanut and its scope. Science & Culture. 22: 150-153.
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11. V. Raghavan & H. K. Baruah. 1959. Effect of time factor on the stimulation of pollen germination and pollen tube growth by certain auxins, vitamins and trace elements. Physiologia Plantarum 12: 441-451.
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15. V. Raghavan & J. G. Torrey. 1963. Growth and morphogenesis of globular and older embryos of Capsella in culture. American Journal of Botany 50: 540-551.

16. V. Raghavan & J. G. Torrey. 1964. Inorganic nitrogen nutrition of the seedlings of the Orchid, Cattleya. American Journal of Botany 51: 264-274.
17. V. Raghavan & J. G. Torrey. 1964. Effects of certain growth substances on the growth and morphogenesis of immature embryos of Capsella in culture. Plant Physiology 39: 691-699.
18. V. Raghavan. 1964. Interaction of growth substances in growth and organ initiation in the embryos of Capsella. Plant Physiology 39: 816-821.
19. V. Raghavan. 1964. Effects of certain organic nitrogen compounds on growth in vitro of seedlings of Cattleya. Botanical Gazette 125: 260-267.
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- in the gametophytes of the fern, Asplenium nidus, by chloramphenicol, puromycin and actinomycin D. American Journal of Botany 54: 198-204.
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C. Effect of Zero Gravity on the Growth and
Pathogenicity of Selected Zoopathic Fungi

by

Dr. J. A. Schmitt
Department of Botany
Telephone: (614) 422-5504

EXPERIMENT TITLE: Effect(s) of Zero Gravity and Radiation on the Growth, Pathogenicity and Ultrastructure of Selected Zoopathogenic Fungi.

EXPERIMENTER: John A. Schmitt, Jr., Professor, Department of Botany
The Ohio State University
1735 Neil Avenue
Columbus, Ohio 43210

TECHNICAL ABSTRACT:

Comparisons of the growth rates, pathogenicities in laboratory animals, and ultrastructure will be made between cells exposed to zero gravity and solar radiation and earthbound cells of a comparable age-in-culture without transfer. The investigations will include Candida albicans and Trichophyton mentagrophytes, both of which are common as inducers of diseased states in humans.

BENEFITS:

The results of the comparisons of the two environments on both organisms could be important for future manned flights. Candida albicans, a yeast, is a common commensal in the oral cavity in about 35% of the human population (Schmitt, 1971, and others), while about 85% of normal, healthy individuals have C. albicans positive stool specimens. Virtually any internal or external stress that alters the immunologic responsiveness of the human host allows the fungus to evoke overt localized or generalized candidiasis. Trichophyton mentagrophytes is one of the two most common causes of tinea pedis ("Athlete's Foot"); surveys indicate that as high as 90% of the adult population has tinea pedis to some degree. It thus seems desirable to have basic data on the effect(s) of the space environment on these two human pathogenic fungi. It is conceivable that new kinds of treatment for candidiasis, and perhaps for trichophytosis, could eventuate from the results of the proposed studies.

1.0 TECHNICAL DISCUSSION OF EXPERIMENT APPROACH, OBJECTIVES, JUSTIFICATION, AND BENEFITS

A variety of past studies with Candida albicans and Trichophyton mentagrophytes have been done in my laboratory, either personally or as theses or dissertations by my graduate students. The strains of both fungi to be examined in the proposed research have been studied for their growth characteristics and to a lesser extent their pathogenicity and/or ultrastructural features. Candida albicans is dimorphic, that is, it grows in vitro as a single-celled, single-budding form at room temperature (23 - 27°C) and in a pseudomycelial form at body temperature (35 - 37°C); T. mentagrophytes is mycelial at either temperature of incubation. Ideally, it would be best to maintain the cultures of

both fungi at $23 \pm 3^\circ\text{C}$. However, since the ambient temperature in the interior of the vehicle will vary around $20 \pm 2.2^\circ\text{C}$, it will be necessary to devise some type of heat exchange incubation system.

In the proposed research, each fungus will be established on routine agar media prior to launch. Subcultures will be prepared and timed so that the cells of C. albicans will be in the log phase of the growth curve at launch time. Culture vessels will be screw-capped tissue culture flasks with an amount of agar medium per vessel such that dessication will not be a critical factor in the survival of the cells for the duration of the flight.

Preliminary growth experiments with C. albicans, incubated at $23 \pm 2^\circ\text{C}$ resulted in large increases in cell numbers over a 4 week period. Viable cell counts, using both pour-plate and vital staining procedures, indicated an initial viable population of C. albicans of 3.2×10^3 cells per ml, compared to a final count of 3.53×10^{11} viable cells. Prior investigations with T. mentogrophytes have given baseline growth data, i.e., increase in dry wt of mycelium per unit time. Experience in maintaining stock cultures of both organisms indicates that they can survive for up to 1 year without subculture to fresh media when stored at 4°C . When exposed to continual more elevated temperatures of incubation, it is probable that the cells of C. albicans will continue to increase in number, but not at the same rate throughout the mission; the fluctuating temperatures should have little effect on the growth of T. mentogrophytes.

It is proposed to carry along parallel studies in my laboratory to those in the LDEF, i.e., an equal number of cultures will be maintained undisturbed at the same temperatures as those in the vehicle for the same length of time. No attempt will be made to simulate zero gravity or solar radiation variables with the earthbound cultures. Baseline studies of the several aspects of the research will have been carried out prior to launch. When notified of the re-entry time and retrieval of the experimental packages, my assistant will initiate the agreed upon procedures with the earth-bound cultures. That is, the assistant will do viable cell counts on C. albicans, determine increase in dry weight of mycelium of T. mentagrophytes, initiate pathogenicity experiments with both fungi, and prepare representative materials for both SEM & TEM. All exposed cultures will be placed under liquid nitrogen to suspend all activities for transport back to my laboratory where similar studies will be done.

The comparative growth studies will be undertaken to determine differences in total growth during the elapsed time of the mission. One peripheral experiment to be included will be to determine if the space environment altered the generation time, i.e., the time to a doubled population of cells, against a baseline of the earthbound cells. Pokorna *et al* (1967) reported several interrelationships between growth rate, respiratory quotient (Q_{O_2}), temperature, and glucose concentration for different strains of C. albicans. In short term experiments,

Yamaguchi (1974) showed morphology-dependent changes in the macromolecular contents (RNA and protein) and respiratory activity to be related to nutrition of C. albicans.

The TEM & SEM studies will be done in an attempt to ascertain any ultrastructural differences that might account for the growth and/or respiratory differences mentioned above. A number of TEM investigators have related ultrastructural differences in C. albicans to morphology of growth form (Yamaguchi et al., 1974), to presence or absence of chemotherapeutic drugs (among other, Irvata, 197), etc.

Relatively fewer SEM studies of C. albicans have been reported. Whittaker and Drucker (1970) studied intact colony morphology of C. albicans and other microorganisms, reporting details of the colonies, the individual surface and interior cells, and interconnecting fine filamentous strands among cells of the colony.. Barnes et al. (1971) presented micrographs of a number of different morphological stages of C. albicans.

The proposed studies will have inherent value that will supplement the data derived from the Apollo 16 mycological data described by Taylor et al. (Biosci. 24, No. 9: 505-511, 1974. Taylor, Biomedical Results of Apollo: 367-380, 1975 and subsequent papers by P. A. Volz). They also should be considered as preliminary investigations to later manned research flights. If, for example, we find that the prolonged exposure of cells of C. albicans increases their pathogenicity, precautions should be taken prior to launch to decontaminate, as much as is possible, the oral cavities and intestinal tracts of the scientists and other personnel of their innate populations of C. albicans. Such decontamination could be achieved through the use of troches of one of the anti-Candida antibiotic drugs and maintained through the regular use of a mouthwash based on cetyl pyridinium chloride.

References:

Barnes, W. G., Flesher, A., Berger, A. E., and Arnold, J. D. 1971. Scanning electron microscopic studies of Candida albicans. Jour. Bact. 106: 276-280.

Marples, M., Somerville, D. A. 1968. The oral and cutaneous distribution of Candida albicans in Raratonga, Cook Islands. Trans. R. Soc. Trop. Med. Hyg. 62: 256-262.

Pokorna, M., Kockova-Kratochvilova, A., Stuchlik, V., and Hronská, L. 1967. Genus Candida Berkhout. IX. Continuous cultivation of Candida albicans. Folia Microbiologica 12: 447-457.

Schmitt, J. A. 1971. Epidemiological investigations of oral Candida albicans. Mycopath. et Mycol. Appl. 43: 65-87.

Whittaker, D. K., and Brucher, D. B. 1970. Scanning electron microscopy of intact colonies of microorganisms. Jour. Bact. 104: 902-909.

Yamaguchi, H. 1974 Dimorphism in Candida albicans. I. Morphology-dependent changes in cellular content of macromolecules and respiratory activity. Jour. Gen. Appl. Microbiol. 20: 87-99.

Yamaguchi, H., Kanda, Y., and Osumi, M. 1974. Idem. II. Comparison of fine structure of yeast-like and filamentous phase growth. Ibid 20: 101-110.

2.0 RELATED WORK AND EXPERIENCE

The principal investigator has been working in medical mycology approximately twenty years. Throughout that time, he has worked mainly with C. albicans as a research tool. A majority of his graduate students has studied C. albicans for their thesis or dissertation research. However, within the past six years, the principal investigator has devoted much of his research time primarily to investigations of Aureobasidium pullulans, the fungus responsible for 80% of the defacement of exterior paints; these studies have involved laboratory growth studies and field studies of the succession of microorganisms on a virgin paint without biocide, culminating in "Paint Mildew".

The principal investigator and his graduate and postdoctoral students have published several papers on the soil mycoflora of Ohio, including both zoopathogenic and saprobic fungi from throughout the state.

The principal investigator is currently a member of: the Technical Committee of the Cincinnati-Dayton-Indianapolis-Columbus Society for Coating Technology; the Candida albicans subcommittee of Committee D-19 on Water (Indicator Microorganisms in Water), American Society for Testing and Materials; and of an ad hoc committee to revise section 915 - Detection of Fungi in Water and Wastewater, Standard Methods for the Treatment of Water and Wastewater, 14th Edition.

Since January, 1973, The Paint Research Institute of the Federation of Societies for Coating Technology has funded the investigations into the growth and microecology of the paint mildew fungus, A. pullulans. The Wm. J. Merrell Co. (now Merrell-National Laboratories) of Richardson Merrell, Inc., funded an epidemiologic study of the incidence of oral C. albicans and its control by the use of a mouthwash, resulting in the 1971 paper by Schmitt cited earlier.

Complete lists of sponsored research and publications of the principal investigator are included in Appendix A.

3.0 EXPERIMENT FACTS

3.1 What specific space properties will it make use of?

Zero gravity and solar radiation effects

3.2 What is the preferred location on LDEF?

Sun side since a passive heat transfer system will be needed to maintain appropriate temperatures of incubation for the fungi and for the solar radiation exposure.

3.3 What are the environmental constraints on the experiment?

(List extremes.)

3.3.1 Temperature range - for cultures of both fungi -
 $22 \pm 3^{\circ}\text{C}$

3.3.2 Vibration and shock (pre- and post-launch and orbit) -
Culture vessels will need to be protected from breakage during lift-off and return

3.3.3 Attitude Control - no special requirements

3.3.4 Radiation (particles and electromagnetic) - no special requirements

3.3.5 Vacuum (space) - Cultures will be in self-contained packages supplied with earth-atmosphere gases

3.3.6 Atmosphere (pre-, during, and post-launch and return) -
Since these organisms are aerobic a typical earth-atmosphere of gases is needed

3.3.7 Magnetic field - no special precautions

3.4 What special protection must be provided to protect the experiment from the earth and space environments?

Cultures should be exposed to earth environment a minimal length of time prior to launch. Culture vessels could be maintained on a clinostat to minimize earth-gravity forces prior to launch.

3.5 Physical description.

3.5.1 Mass - not to exceed limits required by LDEF (< 79 kg.)

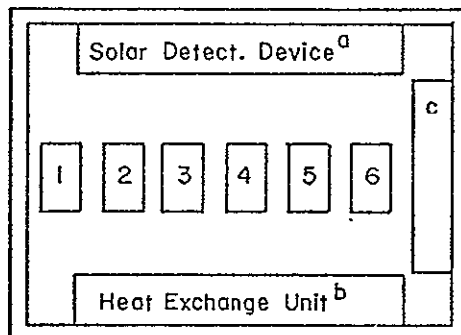
3.5.2 Volume

3.5.3 Surface area required

1 bay should be sufficient for both phases of the experiment.

3.6 Sketch Experiment Including Major Components and Layout for Exposure Experiments.

TOP VIEW (both packages)



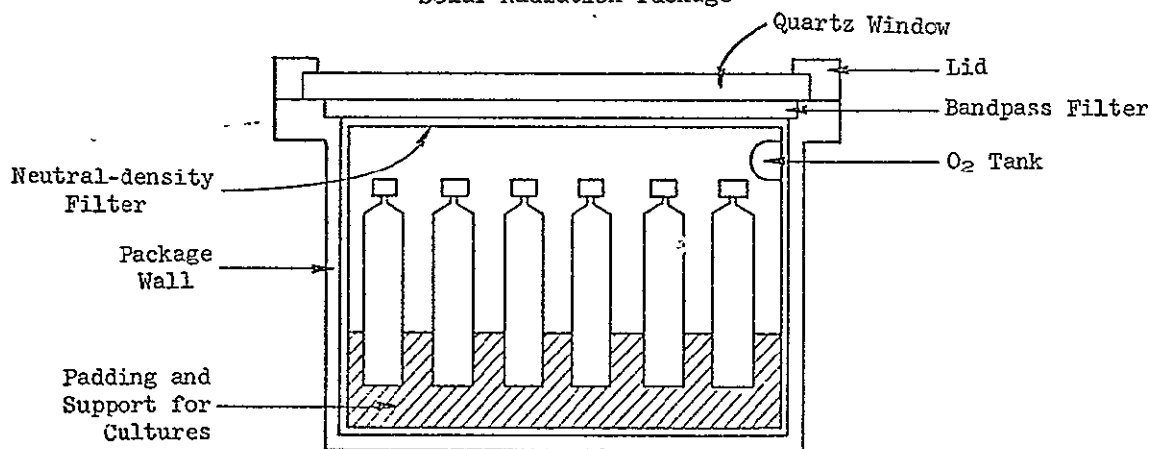
^a: Modeled after Apollo 16 MEED

^b: To be developed at OSU

^c: Device for maintaining O₂ required by combined cultures of both fungi

1,3,5: C. albicans; 2,4,6: T. mentagrophytes

SIDE VIEW
Solar Radiation Package



Non-solar Radiation Package:
(as immediately above without bandpass and neutral-density filters,
but with radiant energy dosimetry system)

4.0 EXPERIMENT HARDWARE

Flight hardware for the package will be developed through modification of the Apollo 16 MEED package as experimentation determines optimal and minimal oxygen requirements and heat release due to respiration of the growing fungi. Basically, the culture vessels will be pre-sterilized plastic tissue culture flasks. Other design details will hinge on the two aspects above and the development of a heat exchange system.

Modifications of the Apollo 16 MEED package envisioned at this time include: changes in container for the fungi-since the MEED accommodated the microorganisms in cuvettes 5 mm on a side, containing the organisms in 50 μ l of liquid or on Millipore filters and was designed for a relatively short flight (11 days), we need to enlarge the containers to accommodate enough agar to last 6 months without dessication and loss of nutrient value; building in a self-contained O₂-source; and adapting the filter-system of MEED to the proposed experiments.

5.0 RESEARCH REQUIRED TO DEVELOP EXPERIMENT

Since both organisms are aerobic, we will need to establish minimal and optimal gas requirements for each fungus, including total volumes and gas ratios needed for a six-month flight.

Since both organisms will be respiring, we will need to know how much heat of respiration is transferred to the experiment package. This will need to be discovered before the passive heat transfer system is devised in cooperation with a mechanical engineer heat transfer specialist.

Both of these sets of data are needed before final design of the ultimate experiment package and its fabrication.

6.0 SPECIAL FACILITIES REQUIRED FOR DEVELOPMENT AND ANALYSIS

To accommodate the several developmental experiments, a walk-in incubator with variable temperature controls is needed.

Specialized equipment: a system designed to supply the necessary O₂ at its optimal concentration for six months; the packaging system for the experiment, which will need to be sealed and self-contained.

7.0 COST ESTIMATE (Manpower)

7.1	Manpower (man-months and dollars)	mm	\$
7.1.1	Experiment design	6	11,886
7.1.2	Development of implementation plan	30	69,980
7.1.3	Ground-based testing	28	83,370
7.1.4	Pre-launch (analysis)	5	11,913
7.1.5	During mission	5	11,821
7.1.6	Post-launch (analysis)	38	86,204
7.2	Hardware (dollars)		
7.2.1	Engineering prototype		75,000
7.2.2	Hardware fabrication		100,000
7.2.3	Pre- and post-launch		25,000
7.3	Other direct costs (computer, travel, etc.)		20,000
7.4	Total Costs		
7.4.1	Manpower	112	275,174
7.4.2	Hardware		200,000
7.4.3	Other Direct Costs		20,000
7.4.4	Total Costs		495,174

8.0 SAFETY CONSIDERATIONS

The experiment will be in a shock-proof container. The individual cultures will be in plastic flasks, so there will be less possibility of breakage. However, so long as the culture vessels remain intact, there is no chance of contamination of personnel, spacecraft or other experiments. If breakage occurs, the fungi will still be confined to the insulated box with its sealed lid.

9.0 INTERACTIONS WITH SPACECRAFT AND OTHER EXPERIMENTS

As mentioned in 5.0 above, the ambient temperature in the LDEF fluctuates excessively for conduct of the proposed experiment. We will develop a passive heat exchange system that will stabilize growth temperatures for both species of fungi at the optimum for maintaining them in their desired growth form. .

10.0 SCHEDULE

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CALENDAR YEARS

MILESTONES		1975			1976			1977			1978			1979			1980			1981		
1	O ₂ Requirements																					
2	1st Test							<=>														
3	Design 2nd Test							<=>														
4	Build 2nd Test							<=>														
5	Run 2nd Test								<=>													
6	O ₂ and Package Design																					
7	Initial design							<=>														
8	Initial Build							<=>														
9	Initial Test								<=>													
10	Heat Exchanger																					
11	Heat of respiration							<=>														
12	Initial design							<=>														
13	Initial Build								<=>													
14	Initial Test									<=>												
15	Final Package Design																					
16	Design										<=>											
17	Build											<=>										
18	Test												<=>									
19	Hardware Anal. & Retest													<=>								
20	Design														<=>							
21	Construction															<=>						
22	Prelaunch																<=>					
23	Mission & Ground Tests																	<=>				
24	Analysis																		<=>			
25																						

NOTES :

APPENDIX A - Scientific Personnel

Curriculum Vitae

John A(rvid) SCHMITT, Jr.

A. Personal Data:

Born: [REDACTED]

Married: 6 September, 1947, to Alyce L. Ridinger

Children: Mark R., born [REDACTED]

Holly L., born [REDACTED]

B. Academic Data:

B.S.: University of Michigan, 2/49 (Zoology)

M.S.: University of Michigan, 2/50 (Botany)

Ph.D.: University of Michigan, 2/54 (Botany - Mycology)

Postdoctoral: Department of Microbiology, Duke University Medical
School - Certificate in Medical Mycology

C. Major Professional Positions:

1974 - Professor, Department of Botany, The Ohio State Uni-
versity

1969 - 1974: Chairman Professor, Department of Botany, O.S.U.

1967 - 1975: Adjunct Associate Professor, Department of Medicine
Dermatology Division, College of Medicine, O.S.U.

1966 - 1971: Associate Professor, Department of Medical Microbiolo-
gy, College of Medicine, O.S.U.

1962 - 1969: Associate Professor, Department of Botany, O.S.U.

1957 - 1962: Assistant Professor, Department of Botany and Plant
Pathology, O.S.U.

1955 - 1957: Instructor, Department of Botany and Plant Pathology,
O.S.U.

1954 - 1955: Assistant Professor, Biology Department, University of
Mississippi, University, Mississippi

1953 - 1954: Professor and Head, Biology Department, Findlay
College, Findlay, Ohio

D. Other Positions:

1. Faculty, F. T. Stone Laboratory, O.S.U.: Summers '60, '63, '65,
'67, '69

2. Professor, NSF - sponsored Summer Institute in Botany for High
School Teachers of Biology, Lawrence University, Appleton,
Wisconsin, Summer, '65

3. Visiting Associate Professor of Botany and Visiting Research
Mycologist, University of Oklahoma Biological Station, Lake

Texoma, Oklahoma, Summer '66

4. Evaluator/Student in a 2-week pilot teaching program, "Introduction to the Sea", a marine biology course initiated by the Lerner Marine Laboratory, 1-2/65 .
5. Consultantships in Mycology to:
 - a. Inland Manufacturing Division, General Motors Corp., Dayton: 4-6/60
 - b. Warren-Teed Pharmaceutical Co., Columbus: 6-8/64
 - c. Allergy Laboratories of Ohio, Inc., Columbus: 1/64 - present
 - d. Merrell National Laboratories, Division of Richardson Merrill, Inc., Cincinnati: 1/65 - 3/75
 - e. Philips Roxane Laboratories, Inc., Columbus: 3/74 - present
 - f. Expert witness for Erickson, Erickson, Lynch, Mackenroth and Arbuthnot, Inc., Sacramento, CA., in litigation of a "paint mildew" case.
6. Participant in a Paint Research Institute-sponsored encounter group of microbiologists and paint scientists discussing Mildew Induced Defacement of Organic Coatings, 15 April, 1971, at Kent State University.
7. Participant in PRI-sponsored 2-day symposium on the microbiology of Mildew Induced Defacement of Organic Coatings, 27-28 March, 1972.
8. Consultantship in Botany to U.S.A.I.D.-O.S.U./Brazil Mission to evaluate research and teaching programs in the Botany Department, Escola Superior de Agricultura "Luiz de Queiroz" (College of Agriculture), University of Sao Paulo, Piracicaba, S.P., Brazil, 29 Oct. - 24 Nov., 1971.

E. Major Committee Assignments at O.S.U.

University:

Council of Student Affairs (1971 - 74; Vice Chairman, 1973 - 74)
Chairman, Subcommittee to Develop Procedures for Legal Representation of Students (1972 - 74)

Graduate Council (1968 - 72)
Executive Committee, 1968 - 70

Policies and Standards Committee, 1970 - 72

Faculty Council, 1971 - 72 (alternate, 1968 - 71)

University Senate, 1972 - 74

Chairman, Committee on Rules and Senate Organization, 1972 - 74

Chairman, Committee on Student Affairs, 1973 - 74

Search Committee for Dean of Undergraduate Programs, 1966 - 67

Committee on Student Standing, 1968 - 70

Committee of Twenty-six, Colleges of the Arts and Sciences, 1970
(to recommend to Faculty Council procedures for enrollment of
students directly in the five constituent colleges of the
confederation)

Council of Academic Affairs, Biological Sciences Subcommittee,
1965 - 66

College of Biological Sciences:

Assistantship Coordinating Committee 1968 - 69

Executive Committee, 1969 - 74

Colleges of the Arts and Sciences:

Search Committee for Dean, Undergraduate Programs, 1966 - 67

Committee of Twenty-six, 1970 - 71

Faculty Senate 1975 - present (Chairman, ad hoc Committee on Grade
Inflation)

Graduate School:

Minority Affairs Committee, 1969 - 71

Departmental:

Planning Committee, 1960 - 64 (Chairman, 1963-64)

Curriculum Committee, 1964 - 67 (Chairman, 1966-67)

Graduate Committee, 1965 - 69 (Chairman, 1967-69)

Promotion and Tenure Committee Chairman, 1969 - 74; member, 1974 -
76

Research Committee, 1974 - 76

Undergraduate Majors Committee, 1974 - present

Other:

OSU Faculty Club: Membership Committee, 1975 - present;
Chairman, 1976 - present

F. Society Memberships:

Mycological Society of America - since 1950 (Sustaining Member
Committee, 1962 - 75, Chairman, 1962 - 68)
Botanical Society of America - since 1950
American Institute for Biological Sciences - since 1955
American Society for Microbiology - since ca. 1960
International Society for Human and Animal Mycoses (Charter Member)
The Medical Mycological Society of the Americas (Charter Member)
The Society of the Sigma Xi
The Ohio Academy of Science (Fellow, 1956)
Cincinnati-Dayton-Indianapolis-Columbus Society, The Federation of
Societies for Coatings Technology - since 1970

Honor Societies:

Phi Sigma - biological sciences - initiated at University of Michigan, 1950
Sigma Gamma Delta - agriculture - initiated at OSU, ca. 1960
Sigma Xi - science - initiated at University of Michigan, 1950

G. Special Honors and Recognitions:

Good Teaching Award, College of Biological Sciences, OSU, 1969
Who's Who in the Midwest, 1970 et seq
Outstanding Educators of America, 1971 Awards volume
International Scholars Directory, 1972 Edition
Dictionary of International Scholars, 1973 Edition
American Man and Women of Science, 13th Edition
Who's Who in the United States, 1975
Notable Americans of the Bicentennial Era, 1976
Who's Who in America, 1976-77

H. Publications:

New and unreported species of hosts for Erysiphe cichoracearum
DC. Plant Disease Reporter 38: 563, 1954.

The status of the name Erysiphe cichoracearum DC. Mycologia 47:
422-424, 1955.

The host specialization of Erysiphe cichoracearum from zinnia,
phlox and cucurbits. Mycologia 47: 688-701, 1955.

Comparative morphology of the zinnia, phlox and cucurbit powdery
mildews. Amer. Jour. Bot. 44: 120-125, 1955.

Aquatic fungi from South Bass and neighboring islands of western
Lake Erie, I. Uniflagellate and biflagellate Phycomycetes. Ohio
Jour. Sci. 61: 283-285, 1961 (with E. S. Beneke)

Idem, II. Additional biflagellate and uniflagellate Phycomycetes. Ibid. 62: 11-12, 1962 (with E. S. Beneke)

Experimental maduromycosis in the laboratory mouse. Mycopath. et Mycologia Applicata 18: 164-168, 1962 (with 3 graduate students).

Variation in susceptibility to experimental dermatomycosis in genetic strains of mice, I. Preliminary studies. Mycopath. et Mycol. Applic. 18: 241-245, 1962 (with 2 graduate students).

Mycological herbaria and medical mycology. Mycopath. et Mycol. Applic. 20: 346-350, 1963.

Variation in susceptibility to experimental dermatomycosis in genetic strains of mice, II. Preliminary results with B alb C and white Swiss strains. Mycopath. et Mycol. Applic. 21: 114-118, 1963 (with 2 graduate students)

Differentiation of Trichophyton rubrum and Trichophyton mentagrophytes by pigment production. Applied Microbiol. 13: 290, 1965 (with M. S. Sudman).

Parasitism of monolayer cultures of dog tissues by Histoplasma capsulatum, I. Preliminary investigations. Mycopath. et Mycol. Applic. 30: 72-78, 1966 (with Aliza Adler).

Variation in susceptibility to experimental dermatomycosis in genetic strains of mice, III. Some comparisons of conventional and gnotobiotic lines of the I.C.R. strain to Trichophyton mentagrophytes. Mycopath. et Mycol. Applic. 32: 306-312, 1967 (with R. G. Miller).

Some observations on aquatic Phycomycetes from Lake Texoma and adjacent parts of Oklahoma. Southwestern Naturalist 12: 311-320, 1967.

Plasmolytic effects of glucose and sucrose on cells of Candida albicans. Mycologia 60: 1107-1112, 1968 (with G. W. Erdos).

Primary mycosis in shrimp larvae. Jour. Invert. Pathol. 13: 351-357, 1969 (with J.H. Hubschman).

Indicator media in the identification of pathogenic fungi. Cutis 5: 1471-1475, 1969 (with P. V. Kurup and E. F. Pagan).

Human-pathogenic fungi in the soil of central Ohio. Ohio Jour. Sci. 70: 291-295, 1970 (with P. V. Kurup).

Epidemiological investigations of oral Candida albicans. Mycopath. et Mycol. Applic. 43: 65-87, 1971.

Isolation of Nocardia from soil by modified paraffin bait method. Mycologia 63: 175-177, 1971 (with P. V. Kurup).

Growth, reproduction and physiology of fungi, in "Mildew Induced Defacement of Organic Coatings (MIDOC): 4th Symposium, Paint Research Institute: 1-18, 1972.

Pathogenicity in mice of strains of Candida albicans (Robin) Berk. isolated from burn patients. Mycopath. et Mycol. Applic. 49: 283-288, 1973 (with Marianita M. Albano).

Numerical taxonomy of Nocardia. Canadian Jour. Microbiol. 19: 1035-1048, 1973 (with P. V. Kurup).

Gliocephalotrichum ohinese, a new species from Ohio soil. Mycologia 65: 948-952, 1973 (with L. H. Huang).

Ohio Ascomycete Notes, I. On Eleutherascus lectardii (Nicot.) von Arx. Ohio Jour. Sci. 74: 234-237, 1974 (with L. H. Huang).

Mildew-Bacteria Symbiosis. Jour. Paint Technol. 45: 31-34, 1973 (with D. E. Padgett).

Mildew Induced Defacement of Organic Coatings (MIDOC) and Related Phenomena. Jour. Paint Technol. 46: 53-59, 1974.

Ohio Ascomycete Notes, II. Talaromyces from soils of southern Ohio. Ohio Jour. Sci. 75: 75-81, 1975 (with L. H. Huang).

The microecology of mold growth. Jour. Paint Technol. 46: 59-64, 1974.

Soil microfungi of central and southern Ohio. Mycotaxon 3: 55-80, 1975 (with L. H. Huang).

Laboratory and successional studies with Aureobasidium pullulans. Jour. Coating Technol. 48: 35-42, 1976 (with D. E. Padgett and J. B. Achmoody).

I. Graduate Students:

1. Past:

a. Ph.D.:

Nielsen, H. S., Jr., "Virulence-Lipid-Dimorphism Relationships in Histoplasma capsulatum", Winter Quarter, 1964.

Creamer, H. R., "Variation in Bacterionema matruchotii", Spring Quarter, 1967.

Broderick, Lynne S., "Light and Electron Microscopy of Vegetative Cells and Developing Zygotes of Isolated Strains of Chlamydomonas mexicana Lewin", Summer Quarter, 1969 (with D. D. Koob).

Pagan, E. F., "Isolation of Human Pathogenic Fungi from River Water", Summer Quarter, 1970.

Caldas, Linda S., "Effects of Various Growth Hormones on the Production of Embryoids from Tissue Culture of the Wild Carrot, Daucus carota L.", Autumn Quarter, 1971 (with W. R. Sharp).

Klapper, Betty F., "Studies on the Extracellular Protease of Aspergillus oryzae: Catalytic Properties and Biological Appearance", Spring Quarter, 1972.

Schaum, K. F., "The Effect of Aeration and Growth Periods on Allergenic Extracts Prepared from Two Strains of Alternaria brassicicola (Schwein.) Wiltshire", Summer Quarter, 1972.

Beery, Grace F., "Isolation and Identification of Immunologically Active Fractions of Helminthosporium maydis", Autumn Quarter, 1972.

Ward, E. R., Jr., "Delayed-type Hypersensitivity Responses to a Cell Wall Antigen Isolated from Coccidioides immitis", Summer Quarter, 1975.

b. M. Sc.:

Albano, Marianita M., "Pathogenicity for Mice of Strains of Candida albicans (Robin) Berk.", Winter Quarter, 1969.

Schwartz, J. N., "The Isolation and Identification of Some Filamentous Oomycetes and Correlations of Their Occurrence with Water Quality", Summer Quarter, 1969.

Mutch, Carole A., "Pathogenicity of Cryptococcus neoformans in Mice", Spring Quarter, 1970.

Manning, D. L., "The Effect of Time, Temperature, Medium and Method of Culture on the Production of Water Soluble Proteins by the Fungus, Alternaria brassicicola", Summer Quarter, 1970.

Foos, K. M., "The Effects of Various Types and Concentrations of Sugars on the Production of Ethyl Alcohol by Saccharomyces carlsbergensis Hansen", Summer Quarter, 1970.

Ward, E. R., Jr., "Some Studies of Two Immune Rabbit Sera Produced by Immunization with Different Preparations", Spring Quarter, 1971.

Chen, Chu S., "Chlorine Disinfection of Four Strains of Candida albicans", Summer Quarter, 1971.

Shung, Ying I., "Effects of pH on Growth and Pathogenicity of Two Strains of Candida albicans", Summer Quarter, 1971.

Harvey, J. B., "Myxomycetes from the Nurnberg, Germany Area with Comparative Studies of Spore Germination in Selected Species", Autumn Quarter, 1972.

Chu, Yi, "Isolation of Keratinophilic Fungi from Soil in the Ohio State University Campus Area", Spring Quarter, 1973.

Musgrave, J. L., "A study of Changes Induced by Candicidin and Dimethyl Sulfoxide in the Growth Rate and Morphology of Human Isolates of Candida albicans", Summer Quarter, 1973.

Achmoody, J. B., "Purification of Allergens from Cladosporium sp. (Conant)", Autumn Quarter, 1973.

Jones, Jeanette, "The Effect of Chlorination on the Survival of Cells of Candida albicans", Autumn Quarter, 1973.

McClure, R. J. "The Effects of Dimethyl Sulfoxide and Temperature on Candida albicans", Spring Quarter, 1975.

Teresk, G. S., "The Influence of Culture Media on the Antigenic Products of Candida albicans", Spring Quarter, 1975.

c. Postdoctoral Fellows:

P. V. Kurup, Ph.D. in Medical Mycology, University of New Delhi, to learn general mycology and to study soil fungi and nocardiae of Ohio.

L. H. Huang, Ph.D. in Soil Mycology, University of Wisconsin-Madison, to learn medical mycology and to study soil fungi of Ohio.

2. Present:

a. Ph.D.:

Albano, Marianita M., "Effect of Clotrimazole on the Ultra-structure of Histoplasma capsulatum in vitro" (Summer

Quarter, 1976).

Jones, Jeanette, "Nutritional Studies with Piedraia hortae" (Summer Quarter, 1976).

b. M.Sc." (two inactive students)

J. Research Grants:

1. Antigenicity of Geotrichum candidum Strains (with M. S. Rheins, Microbiology); 1-year; College of Agriculture, OSU.
2. Ultrastructure of Histoplasma capsulatum in Cells of Monolayer Cultures of Canine Kidney; 1-year; College of Biological Sciences, OSU.
3. Incidence of Oral Candida albicans and the Interrelationships of C. albicans and the Oral Bacterial Flora; 2 months; Wm. S. Merrell Co., Cincinnati, Ohio.
4. Marine and Tropical Mycology; 1-month cruise expenses; Bahamas Biological Survey, ONR/Lerner Marine Laboratory.
5. Ecology of Aureobasidium pullulans as the Casual Agent of Mildew of Organic Coatings; 18 months; Paint Research Institute.
6. Commensal Relationships of Aureobasidium pullulans and Bacteria in MIDOC; 2 years; Paint Research Institute.
7. Effect of Zero Gravity on the Growth and Pathogenicity of Selected Zoopathogenic Fungi; 6 months; NASA-Langley Research Center.

D. Importance of Gravity to Survival Strategies
Of Small Animals

'by

Dr. G. W. Wharton, Director
Acarology Laboratory
College Biological Sciences .
Telephone: (614) 422-7180

EXPERIMENT TITLE: Importance of Gravity to Survival Strategies of Small Animals.

EXPERIMENTERS: G. W. Wharton, Professor & Director, Acarology Laboratory
Dana L. Wrensch, Research Associate, Acarology Laboratory
Francis A. Kulacki, Associate Professor, Mechanical Engineering

The Ohio State University Research Foundation
1314 Kinnear Road
Columbus, Ohio 43212

TECHNICAL ABSTRACT:

Terrestrial resources are distributed along a gravitational gradient and small animals use the gravitational field for orientation. Descriptive and quantitative comparisons of structure, physiology, population densities and subsequent behavior of earthbound and orbiting colonies of animals will lead to understanding of the importance of gravity to these populations. Gravitational effects may be direct or mediate the selection of genetic variants that are preadapted to weightlessness.

BENEFITS:

The influences of gravity that will be revealed by these studies will provide new criteria for evaluating the influence of this force in living systems. The result will also be important to the planning of self-contained ecosystems designed for support of commercial or public exploitation of space in the vicinity of the earth or extended travel in outer space. These gravitational influences must be identified and described before an estimate of their benefits on earth can be made.

1.0 TECHNICAL DISCUSSION OF EXPERIMENT APPROACH, OBJECTIVES, JUSTIFICATION, AND BENEFITS.

We plan to design and fabricate a passive life support system for the LDEF that will be suitable for the sequential development of several generations of small animals (mites weighing less than 0.05 mg). Comparison of generations developed under weightless conditions with earth controls will allow both the direct and indirect effects of gravity on the form of the mites to be evaluated. Indirect effects include trade-offs between gravitational and tactile stimuli in terms of sensory deprivation and substitution of adhesive forces for the stabilizing influence of weight. If such trade-offs are made, mean setal lengths should increase, holdfast organs should become larger and adhesive secretions should be enhanced as selection of genetic variants possessing longer setae and more effective holdfast mechanisms progresses in a weightless environment.

The life support system will consist of a wrap-around heat sink with a capacity of over 1,000 Kcal at 25°C by virtue of the heat of fusion of materials with suitable melting points such as tertiary butyl alcohol. The sink will have the form of a short pipe of rectangular cross section. Flight chambers will provide an atmosphere for mite cultures and sinks for organic wastes, pheromones, and water vapor. The water vapor sink will also serve as a water source. The flight chambers will be mounted on 2 fiberglass panels of rectangular shape so that the resulting configuration will just fit in the wrap-around heat sink. The entire experiment package will be constructed to fit and be secured to an LDEF experiment tray.

As candidates for flight we have selected four species that are major pests of man: the two most common house dust mites, Dermatophagoides pteronyssinus (Trouessart 1897) and D. farinae Hughes 1961, and the two most common stored products species, Acarus siro L. 1758 and Tyrophagus putrescentiae (Schrank 1781). Because they are major pests, our knowledge of the biology of the candidate species is now in an advanced state. Physiological tolerances to temperature and humidity extremes are known. Oxygen and nutritional requirements have been determined. They are able to withstand freezing or excessive heat for short periods and are able to extract water from unsaturated air. These species can be expected to produce 5 to 12 generations in six months time. During the preflight period, the influence of gravity and substrates on population patterns and developmental events of the candidates will be determined. Their viability under various gas mixtures will be tested.

The mites will be cultured in an elongate nylon pouch subdivided along its length by barriers that will permit movement of larvae from compartment to compartment but not post-larval developmental stages. The external mesh size is 53 µm and small enough to retain all life stages while permitting free flow of gases. The larval sieves have openings of 74 µm. It has already been determined that cultures do well in these pouches and that larvae can move through the 74 µm but not the 53 µm mesh. Each flight chamber will include a single culture pouch with appropriate numbers of compartments for the generations of the species in question. The pouches will be free-floating thus serving as stirrers.

We expect that strains of T. putrescentiae and A. siro that are genetically programmed to be more or less geopositive or geonegative can be isolated. Geonegative and geopositive strains of each of these species will be exposed to weightlessness. Inbred lines of mites having relatively invariant and different structural conformation will be developed and then hybridized (F₁, F₂) for flight, permitting a genome of known phenotypic potentiality to undergo the selective impact of weightlessness. Characterization and comparison of distributions of morphological variation between orbited and control populations will reveal trends and consequences due to weightlessness. Each of the

candidate species will be used. Whether comparisons of strains within species will be productive will be decided on the basis of the above studies. Study of strains will be attempted only if it appears that their inclusion in the flight promises to be more informative than the greater numbers of individuals of each species that could develop in a fewer number of larger flight chambers. However, the priority for space in flight will be given to different experiments with the goal of maximizing the information retrieved through comparison with controls. Replication of experiments will be limited to laboratory controls.

During the flight period, laboratory control cultures will be opened compartment by compartment as they develop significant numbers, providing mites of known generation. The specimens will be examined by phase contrast microscopy so that any selective pressures exerted by the pouches (e.g., larval sieves) on succeeding generations can be detected.

Following the flight, laboratory controls will be compared compartment by compartment with the unorbited flight controls. Unorbited and orbited flight chambers will be compared as well as the mite cultures from them. Cultures of mites from the most recently invaded compartments will be made and these mites will be used to study differences in geotactic responses of orbited and unorbited mites as well as other behavioral and physiological properties.

Through interpretation of these comparisons we will be able to distinguish among a number of possible causes for the observed differences between mites and cultures from orbited and unorbited flight chambers. For example, differences that appear with equal frequency from compartment to compartment from the first to last can be ascribed to the direct effects of the absence of gravitational force on the developmental processes. Those differences that are more pronounced in the final generations than in the first will most probably have been caused by selection of genetic variants more suitable to a weightless environment. A careful analysis of such variants in comparison with forms they seem to displace should offer tools for investigation of extremely subtle gravitational influences. Of utmost importance will be the demonstration of the ability or lack of ability of animals to adapt to weightlessness and to succeed generation after generation. Such a demonstration is essential as a prelude to design of self-contained orbiting ecosystems.

Further technical discussion is contained in Appendix A.

2.0 DISCUSS RELATED WORK AND EXPERIENCE

G. W. Wharton - Principal Investigator

Highest degree: Ph.D., Duke University, 1939

1968 - date: Professor and Director, Acarology Laboratory
 1961 - 1968: Professor and Chairman, Department of Zoology and Entomology, Ohio State University
 1953 - 1961: Professor and Head, Department of Zoology, University of Maryland
 1939 - 1953: Instructor - Associate Professor, Department of Zoology, Duke University

Bibliography: 124 titles; research interests: physiology of Acari and water balance

Francis A. Kulacki - Co-Investigator

Highest degree: Ph.D., University of Minnesota, 1971

1975 - 1976: Associate Professor, Mechanical Engineering, Ohio State University
 1971 - 1975: Assistant Professor, Mechanical Engineering, Ohio State University
 1966 - 1971: Graduate Research and Teaching Associate, Department of Mechanical Engineering, University of Minnesota, Minneapolis
 1963 - 1966: Graduate Fellow and Research Assistant, Institute of Gas Technology, Chicago, Illinois
 1960 - 1963: Junior Engineer, Summer, Gas Division, Baltimore Gas and Electric Company, Baltimore, Maryland

Bibliography: 17 titles; research interests: thermal sciences

Dana L. Wrench - Co-Investigator

Highest degree: Ph.D., Ohio State University, 1972

1975 - 1976: Research Associate, Acarology Laboratory, Ohio State University
 1972 - 1975: NIH Postdoctoral Trainee, Acarology Laboratory, Ohio State University
 1969 - 1970: Graduate Research Assistant in developmental genetics, Ohio State University

Bibliography: 12 titles; research interests: population biology and genetics

3.0 EXPERIMENT FACTS

3.1 What specific space properties will it make use of?

Weightlessness. The experiments require absence of gravitational force, not just a change in direction of application of the force.

3.2 What is the preferred location on LDEF?

Leading side	<u>2</u>	Space end	<u>3</u>
Trailing side	<u>2</u>	Interior	<u>not acceptable</u>
Earth end	<u>1</u>		

3.3 What are the environmental constraints on the experiment?

(List extremes.)

3.3.1 Temperature range - Mean temperature $25^{\circ}\text{C} \pm 5^{\circ}\text{C}$;
allowable extremes for no longer than a few hours:
 -18°C and $+45^{\circ}\text{C}$.

3.3.2 Vibration and shock (pre- and post-launch and orbit)
Not significant.

3.3.3 Attitude control - Panel must be alternately exposed
to high and low temperatures during each orbit.

3.3.4 Radiation (particles and electromagnetic)
Not significant.

3.3.5 Vacuum (space)
Not significant.

3.3.6 Atmosphere (pre-, during, and post-launch and return)
Not significant.

3.3.7 Magnetic field
Not significant.

3.4 What special protection must be provided to protect the
experiment from the earth and space environments?

It must be held as close to 25°C as feasible. 21°C scheduled
for holding at the launch site is acceptable, but several
days at temperatures below 20°C could be harmful.

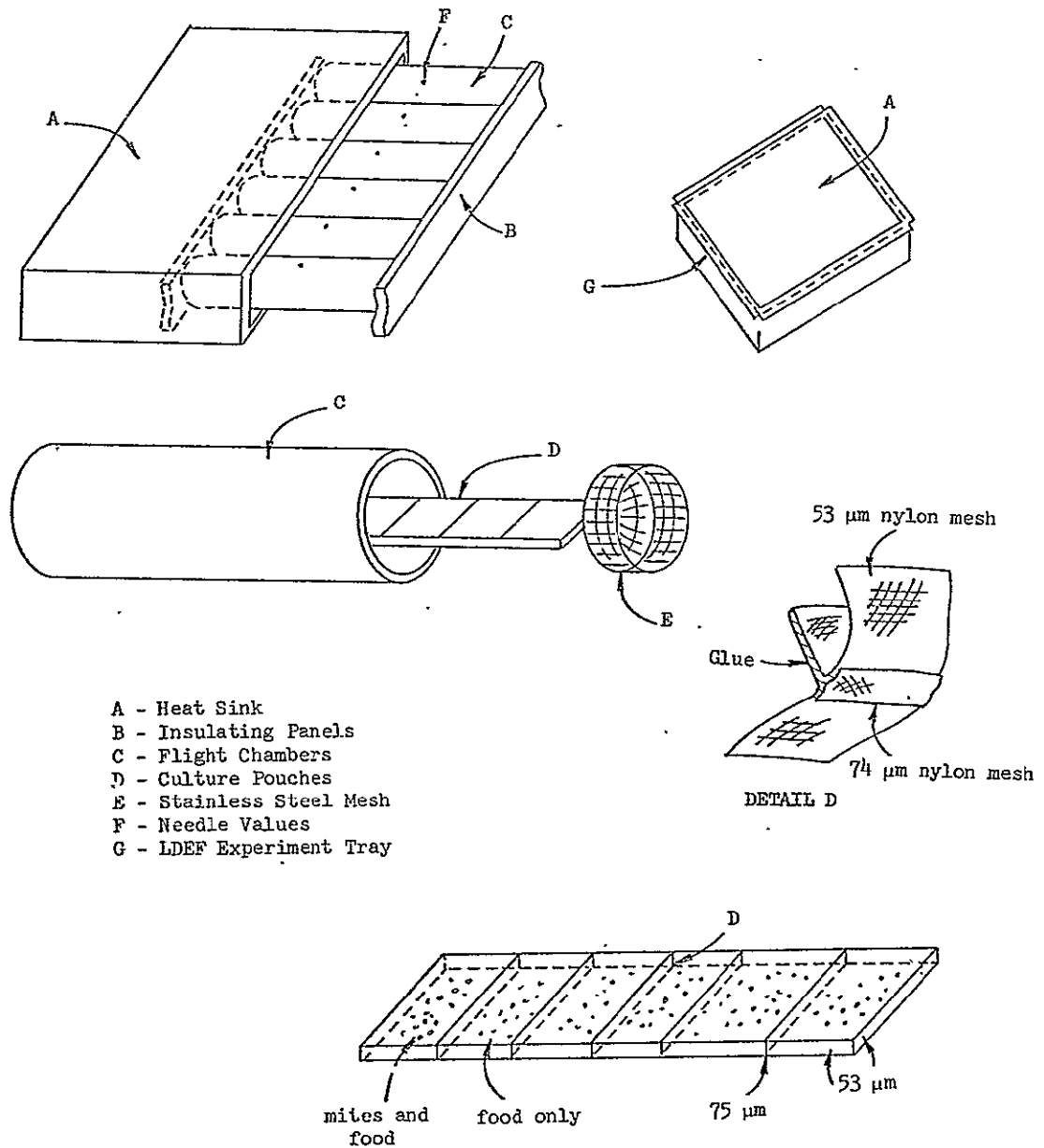
3.5 Physical description.

3.5.1 Mass - 79 kg

3.5.2 Volume - 0.369 m^3

3.5.3 Surface area required - 1.14 m^2

3.6 Sketch Experiment Including Major Components and Layout for Exposure Experiments. (Not to scale.)



4.0 EXPERIMENT HARDWARE

The heat sink will be a metal casing surrounding a material having a melting point about 25°C and a significant heat of fusion, such as tertiary butyl alcohol. The amount of tertiary butyl alcohol will be as much as will be permitted by the weight load of the experimental tray. This will provide maximum thermal stability for the experiment.

The flight chambers will be cylinders 15 cm in diameter with a minimum capacity of 10 liters, C in Item 3.6. The flight chambers will be equipped with two closures that will fit in an insulating panel, B. One closure will contain activated charcoal and the other a hygroscopic material such as filter paper that is in equilibrium with 75% R.H. These materials will be held in place by stainless steel mesh, E. Each flight chamber will be fixed between two insulating panels that will fit into the space provided in the heat sink, A. Needle valves, F, will be provided for the introduction and removal of gas mixtures. Vents, H, in the insulating panels will preclude the hazard of excessive pressure differentials in the experimental package.

Culture pouches, D, will be made from nylon bolting cloth of two meshes. The outer wall of each elongate pouch will be made of 53 μ m mesh that will prevent escape of all life stages of the mites. Each elongate pouch will be subdivided into a number of compartments so that larvae can move from compartment to compartment through the 74 μ m larval sieve. This will partially separate one generation from the next.

The entire experimental package will be secured inside an experiment tray, G, for flight.

The precise dimensions of the various components of the hardware and their attachment together will be determined during preflight tests. Choices of kinds and thicknesses of metals for flight chambers and heat sink will be made after testing for stress-related responses and fiberglass or some other material will be studied for best insulating and strength properties. Similarly, the dimensions of culture compartments, best gas mixtures, and food/substrate combinations will be experimentally determined. As a result of these tests, either 6 short flight chambers as illustrated or 4 long flight chambers extending along the length rather than across the breadth of the experimental package will be used.

Existing technical skills and materials will be sufficient for design and fabrication of hardware.

5.0 RESEARCH REQUIRED TO DEVELOP EXPERIMENT

The biological research required is discussed in Section 1.0 and Appendix A as an integral part of the experiment. The studies involving the life support system will require consultation with LRC and testing of specific materials. No new technology is required.

6.0 SPECIAL FACILITIES REQUIRED FOR DEVELOPMENT AND ANALYSIS

The only special facility required is the life support system.

7.0 COST ESTIMATE (Manpower)

7.1	Manpower (man-months and dollars)	mm	\$
7.1.1	Experiment design	13	22,789
7.1.2	Development of implementation plan	39	68,368
7.1.3	Ground-based testing	78	143,440
7.1.4	Pre-launch (analysis)	13	22,556
7.1.5	During mission	18	36,114
7.1.6	Post-launch (analysis)	48	105,024
7.2	Hardware (dollars)		
7.2.1	Engineering prototype		50,000
7.2.2	Hardware fabrication		25,000
7.2.3	Pre- and post-launch		20,000
7.3	Other direct costs (computer, travel, etc.)		26,250
7.4	Total Cost		
7.4.1	Manpower	209	398,291
7.4.2	Hardware		95,000
7.4.3	Other Direct Cost		26,250
7.4.4	Total		519,541

8.0 SAFETY CONSIDERATIONS

The tertiary butyl alcohol enclosed in the heat sink is a potential hazard. If the LDEF were exposed to temperatures above 82°C, the alcohol might split its container and leak out where it would be a fire hazard. The flight chambers will probably contain air-oxygen mixtures, but accidents to them in anything less than a catastrophic event appear to be unlikely. In the event that tertiary butyl alcohol is eliminated as the temperature controlling material, we propose to use two sinks containing different materials that will have melting points about equally above or below 25°C (section II-B, Appendix A).

9.0 INTERACTIONS WITH SPACECRAFT AND OTHER EXPERIMENTS (e.g., thermal, radiation, mechanical).

The mass of the experiment is planned to be at the upper limit of the experiment tray design. There will be no radioactive and mechanical interactions with other experiments. Thermal interaction with other experiments will be negligible due to self-contained heat sink.

10.0 SCHEDULE

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CALENDAR YEARS

MILESTONES		1975			1976			1977			1978			1979			1980			1981		
1	Establishment of Inbred Lines						↔															
2	Establishment of Geotactic Strains						↔															
3	Design of Pouches						↔															
4	Bread Board Flight Chambers						↔															
5	Gas Mixture Tolerance Tests						↔	→														
6	Influence of G-Field on Mites						↔	→														
7	Culture/Chamber Optimization						↔	→														
8	Chamber Fabrication						↔															
9	Primary Development of Selected Lines						↔	→														
10	Heat Sink/Life Support Design/Fabr/test						↔	→														
11	Primary (Selected) Strains in Chambers							↔	→													
12	F ₂ Development							↔	→													
13	F ₁ in Chamber (Primary Strains)								↔	→												
14	F ₁ in Chamber Vibration/test							↔	→													
15	Maintenance of Selected Lines							↔	→													
16	Analysis of Lab Controls													↔	→							
17	Final Package in Experiment Tray & Test										↔	→										
18																						
19																						
20	Experiment Design						↔	→														
21	Development of Implementation Plan							↔	→													
22	Ground Based Testing							↔	→													
23	Pre-Launch Period													↔	→							
24	During Mission													↔	→							
25	Analysis (Post Flight)															↔	→					

NOTES:

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Appendix A - Technical Discussion

Gravity is a uniform and pervasive force under which all life has evolved. Man's ability to exist and perform tasks in a weightless environment has been made possible through artificial aids, e.g., supporting functions of energy intake and waste removal. Animals less sophisticated than man will be a focus of applications of future space technology, including the development of self-sustaining ecosystems to accompany him in future long term space travel. We know virtually nothing about animals' unassisted ability to reproduce in weightlessness or the consequences of this new environment to their other normal functions. The normal behavior of animals is frequently accompanied by genetically programmed back-up systems capable of responding to altered or new environmental conditions. Discovering and interpreting the impact of adjustments and alterations in the fundamental responses of animals after a period under weightlessness is the focus of this proposal.

The LDEF as described in a number of pamphlets and guides (Anonymous, LRC December 1975, April 1975, 1974, Mayeux 1974, Wrobel & Dodds 1973) offers opportunities for testing the effects of continued weightlessness on several successive generations of rapidly reproducing small animals. In studies conducted on Biosatellite II, the importance of developing techniques to accomplish such studies was mentioned by most contributors (Saunders ed. 1971). In addition to a short generation time, small animals have the advantage of minimum requirements for space, food, water and O_2 (Sullivan et al. 1976). Many also have complex behavioral patterns (Schöne 1975, Balashov 1972, Camin 1953, 1963, Fraenkel & Gunn 1961, Solomon 1937), significant genetic variability (Hodgson 1975, Pence et al. 1975, Fain 1968, Goksu et al. 1960), and well studied morphological features. In the second printing of his second volume of Growth and Form, D'arcy Thompson (1952) states "The form of any portion of matter . . . and the changes of form which are apparent in its movements and in its growth, may in all cases be described as due to force." In short, the form of an object is a "diagram of forces". Thus the direct influences of gravity on form of small animals will be apparent in the structures of the first generations grown under weightless conditions. Responsibility for alterations in cell development has been attributed to weightlessness (Vaulina et al. 1971). Other influences of gravity resulting in selection of more suitable genetic variants will become more recognizable in each succeeding generation.

Despite their small size, gravity influences the complex behavior of many mites. For example, Dermatophagoides pteronyssinus (Trouessart 1897), tends to exploit the bottom of culture jars while D. farinae Hughes 1961, permeates the entire matrix of the culture material as well (Wharton 1973). Some mites that move up when they are in moist environments will become positively geotactic when they are drying out (Nef 1971). The mechanism that enables water vapor to be gained from

unsaturated air by acarid mites is designed so that the hygroscopic fluid flows from the dorsal to the ventral region (Brody et al. 1976, Wharton 1976). Tyrophagus putrescentiae (Schränk, 1781) appears to be polymorphic for geotaxis and it is possible that genetic strains of T. putrescentiae can be developed, such as has been done for Drosophila (Erlenmeyer-Kimling et al. 1962, Hirsh & Erlenmeyer-Kimling 1961, 1962, Erlenmeyer-Kimling & Hirsch 1961, Hirsch 1959, Hirsch & Tryon 1956), to study the influence of weightlessness on the maintenance of geotactic differences in the strains. Acarus siro L. 1758, has not been studied with respect to gravitational responses, but it is probably similar to T. putrescentiae in its responses and has the advantage of growing well at low rather than high temperatures. T. putrescentiae and A. siro do well on large food particles that are enhanced as a food source when they serve as a substrate for contaminating fungi (Thomas & Dicke 1971, 1972), while species of Dermatophagoides seem to require finely divided food particles. All four of the above species are major pests and all have been the subject of recent extensive studies (Wharton 1976, Furumizo 1973, 1975, Gridelet et al. 1973, Bronswijk & Sinha 1971, Cutcher 1970, Sinha et al. 1970, Solomon 1969, Voorhorst et al. 1969, Fain 1967, Spijksma 1967, Griffiths 1964, Hilsenhoff & Dicke 1963, Solomon 1962, Hughes 1961, Knülle 1959, Solomon 1953).

Because they can be readily cultured and are so well known, we have selected these species as candidates for culturing on the first flight of the LDEF. We know that separate environments suitable for the development of colonies (Furumizo 1973, Arlian 1972) can be included in a single experiment tray on the LDEF. The limiting parameter is O_2 availability, but 6 chambers each containing 10 l of air at 1 atm pressure can be accommodated. A population of 50,000 D. farinae requires no more than 2 liters of O_2 for six months (Arlian 1975a). Theoretically, if a culture could maintain a log growth phase begun with 10 mating pairs of D. farinae, about 24,000 individuals would be produced in six months if the temperature were held at about 21.1°C and over 7 million would be produced if temperatures fluctuated about a mean of 25°C. Based on data of Furumizo (1973) and a method of determining the intrinsic rate of increase developed by Lewontin (1965), the values for r for D. farinae at various temperatures are: 21.1°C, 0.0426; 22.1-28.8°C, 0.0738; 26.6°C, 0.0978; and 32.2°C, 0.0999. The formula for the number of mites (N) for all generations at any time (t) is $N_t = N_0 \exp (rt)$ where N_0 is the initial number, t is in days, and r has dimensions of $1/t$. Estimates of growth rates based on data from D. farinae using other techniques (Wilson & Bossert 1971) compare favorably with the above numbers. D. pteronyssinus has similar properties but they are not yet as well determined (Arlian 1975b).

The four candidate species have different patterns of population growth. T. putrescentiae has an intrinsic rate of increase of r of 1.09/day (Boczek & Legat 1973) and a generation time of 14.9 days. Acarus siro populations develop less rapidly than T. putrescentiae (Sinha & Wallace 1973, Solomon 1953, 1962, 1969) but much faster than D. farinae. D. pteronyssinus also increases in numbers more rapidly

than D. farinae (Wharton 1976). T. putrescentiae, A. siro, and D. farinae have been found to survive for a time at -18°C (Paul & Sinha 1972, Sinha 1964, Hilsenhoff & Dicke 1963). A. siro can grow from 10°C to 30°C and does well at temperatures as low as 15°C or as high as 25°C (Solomon 1962, 1969). Both T. putrescentiae and D. farinae have high growth rates at 25°C (Furumizo 1973, Hilsenhoff & Dicke 1963). D. pteronyssinus also appears to have maximum growth rates near 25°C (Spieksma 1967). D. pteronyssinus can withstand 50°C for a few hours (Kinnaïrd 1974). All four species do well on food in equilibrium with an atmosphere of 75% relative humidity (Arlian 1975a, Larson 1969, Knülle 1965), although T. putrescentiae does better at humidities in the 80's (Cutcher 1973).

Mites obtain water from their food or if no edible source is available, by actively taking up water from the air (Arlian & Wharton 1974, Rudolph and Knülle 1974, Wharton & Devine 1968, Kanungo 1963, 1965, Wharton & Kanungo 1962). Lower permissible limits of water activity, known as Critical Equilibrium Activity (CEA) for fasting mites are .70 (=70% R.H.) for D. farinae (Larson 1969), .71 for A. siro (Knülle & Wharton 1964), .73 for D. pteronyssinus (Arlian 1975b) and .70 to .84 for T. putrescentiae (Cutcher 1973).

Mass cultures of all the species can be developed (Stepien & Rodriguez 1973) and are available in our laboratory.

Centrifuging such small creatures as mites at over 4000 RPM and subjecting them to over 50 G did not injure them.

Weightlessness will have effects on the environment as well as on the biology of mites. Due to weightlessness, ordinarily predictably distributed resources will become randomized. Encounters with unattached food particles and life stages of mites will represent novel experience; objects without stability. Presence or absence of gravity represents two extremes in which selective pressure may operate. Structures and functions favored by selection in a gravity environment would be expected to be selected against or no longer selected for in a weightless environment. For example, selective pressures favoring geotaxis would be absent in a weightless situation, but selection would favor any traits improving tactile responsiveness. Holdfast organs such as pedal suckers and claws would be expected to become larger and tactile setae should become longer. Such enlargements would be selected to compensate for the lack of gravity by enhancing structures and behavior associated with tactile perception.

Other aspects of mite biology should also be susceptible to selection. Eggs and quiescent stages are normally fixed to a substrate, effectively implementing hatching and moulting. To facilitate these functions in a weightless environment, increased adhesiveness of secretions and excretions would be expected to be selected for. Because water moves down a gravitational gradient along the podocephalic canal,

the width of the canal should be reduced by selection in a weightless environment (Brody et al. 1976, Wharton 1976). Without gravity, surface forces assume greater importance as mechanisms of movement along the canal, and these forces would be improved by narrowing of the canal. Pharyngeal muscles which normally must pump fluids against a gravitational pull, would be expected to become smaller in response to the removal of selective pressure. To increase copulatory efficiency in a weightless environment, modifications of sexually dimorphic structures such as leg spurs and anal suckers, which are believed to enhance mating ability, would be selected for.

In order to increase the opportunities for the hypothesized selective events, strains of mites with known phenotypic potentiality will be developed. A large number of inbred lines will be established and monitored so that specific structural conformations expected to be sensitive to selection under weightlessness can be isolated. Hybrids among the inbred strains will be used in flight because hybridization reconstitutes much of the underlying genetic variability that is reduced by inbreeding while retaining the genome's specific ability to respond to the anticipated selective pressures.

The preceding paragraphs demonstrate that:

1. A suitable flight chamber to maintain an atmosphere and substrate suitable for the rearing of mites can be built.
2. Four candidate species of mites are available.
3. Observable characteristics that are related to the weightless environment can be studied.
4. The experiment has a splendid chance of successful completion.

We propose to control temperature by using a heat sink that contains a single material with a melting point of about 25°C or two sinks that contain different materials that will have melting points about equally above or below 25°C (Hodgman et al. 1959). The heat sink will be wrapped around the flight chambers and will radiate energy to them. Such a system with appropriate surface treatment should be able to maintain a $25^{\circ}\text{C} \pm 5^{\circ}\text{C}$ in the flight chambers with a mean about 25°C (Duffie & Beckman 1976, Welty 1974, Brown & Marco 1958, Daniels & Duffie 1955). Thus it appears that it will be feasible to include this experiment on the first LDEF mission.

During the preflight period of our studies, 1 October 1976 through 31 March 1979, data will be collected so that the specific biological systems can be selected and the best flight chambers and heat sink can be designed and fabricated.

Using mites from mass cultures, the following biological studies will be conducted on each candidate species.

Engineering studies are also included in the outline.

PREFLIGHT RESEARCH SCHEDULE

(Experiment Design, Implementation Plan, Ground-Based Testing)

1 October 1976 - 31 March 1979

I. Biological studies

A. Influence of gravity

1. Population patterns in nylon pouches

- a. Pouch vertical, food at bottom
- b. Pouch vertical, food at top
- c. Pouch vertical, food throughout
- d. Pouch horizontal, food at North end
- e. Pouch horizontal, food at South end
- f. Pouch horizontal, food throughout from North to South

2. Developmental events

One of the major differences between the earth environment and the weightless environment of the LDEF will be the difficulty mites may encounter ingesting weightless food. On earth, food particles have sufficient stability by virtue of their weight and inertia so that mites can move from piece to piece without displacing the food drastically. Such stability is particularly important during hatching and moulting. Egg shells that are glued to a substrate that has enough stability to enable the newly hatched larvae to leave the shell behind will be most successful as will nymphs and adults that emerge from exuviae fixed to the substrate. The attachment of males to pharate females and copulation with females after they emerge will be more difficult in the weightless environment. The culture pouches will have to be designed so that the external mesh can serve as a suitable substrate for these activities for many if not all the mites involved.

- a. Orientation of quiescent stages with respect to gravity

- b. Comparison of undisturbed quiescent stages with inverted quiescent stages and detached quiescent stages (Ellingsen 1974)
 - 3. Survival studies of fasting mites above CEA
 - a. Upright
 - b. Inverted
 - B. Substrates and culture containers

The intrinsic rate of increase of mites is not only regulated by temperature but can also be modified by amount and distribution of food. A nylon net chain of interconnected food-containing pouches will be in each flight chamber and will be designed to adjust the rate of increase to about 2,000 mites per pouch. The external net will have openings 53 μ m and will not allow mites to escape. The net between the pouches will be 74 μ m across and larvae (first active stage) will be able to move through. Mites will be started in a pouch at one end and enough pouches for each new generation will be provided. Thus, in the case of Tyrophagus putrescentiae (Schränk, 1781), there will be 12 pouches. The initial pouch will contain mites from generation 1 through 12, the second pouch, generations 2 through 12, up to the 12th pouch where only generation 12 will be represented, if larvae do not pass through more than a single pouch. It is unlikely that larvae would pass through a pouch that was previously unoccupied, but the probability of such an occurrence will be determined during the preflight and flight periods. Mites have been reared in such pouches but preflight studies are required to determine the best dimensions and quantities of food for each candidate species.

 - 1. Nylon pouch with powdered food
 - 2. Nylon pouch with food cubes
 - C. Gas mixtures supporting normal activity in 10 l flight chambers
 - 1. Mixtures at one atmosphere
 - a. Minimum pp O_2 in air at suitable humidity
 - b. Maximum pp O_2 in air at suitable humidity
 - c. Maximum pp CO_2 in air at suitable humidity

- d. Humidity limits at extremes of O_2 and CO_2
 - 2. Mixtures above one atmosphere
 - a. Air
 - b. O_2 + air
 - c. O_2
- D. Selection
 - 1. Positive geotactic strain or species
 - 2. Negative geotactic strain or species
 - 3. Interaction between behavior and environment
 - a. Influence of humidity
 - b. Influence of temperature
 - 4. Multiple inbred strains
- E. Maintenance of flight chamber atmosphere
 - 1. Organic waste and pheromone sorption
 - 2. Water vapor sink
 - 3. Temperature indicators
 - a. High: wax threads of suitable melting points
 - b. Low: glass bubbles with aqueous solutions of different freezing points
- F. Tests of generation times in culture pouches
 - 1. In desiccators
 - 2. In flight chambers at best gas mixtures and pressures as determined in C above
 - a. With activated charcoal and water vapor sink
 - b. Without activated charcoal

II. Engineering

A. Flight chambers

The first task will be the production of 18 flight chambers. These will be cylinders capped at each end with chambers that can serve as a source and sink for water vapor or activated carbon for absorbing volatile organic wastes and pheromones. Hygroscopic materials will act as a source or sink for water at an appropriate humidity. Each cylinder will be equipped with a needle valve so that they can be filled with appropriate gas mixtures.

B. Heat sink

One candidate design for the heat sink will be an aluminum casing filled with tertiary butyl alcohol (m.p. 25.45°C, b.p. 82.8°C, heat of fusion 21.0 cal/g, density 0.7887 g/ml). The amount of alcohol used will be the maximum allowable by the weight limits of the experiment. It will surround the flight chambers, which will be held in place by attachment to fiberglass panels (see sketches). If tertiary butyl alcohol is too dangerous because of its inflammability and relatively low boiling point, other materials having suitable melting points (Hodgman et al. 1959) are,

	Melting Point	Heat of Fusion
(a) $\text{Na}_2\text{CrO}_4 \cdot 10 \text{H}_2\text{O}$	23	39.2
(b) $\text{Na}_2\text{SO}_4 \cdot 10 \text{H}_2\text{O}$	31	51.3
(c) $\text{C}_3\text{H}_5\text{C}_6\text{H}_4\text{OCH}_3$	21.5	25.8
(d) $\text{CH}_3\text{C}_6\text{H}_4\text{Br}$	27.6	20.9
(e) $\text{C}_6\text{H}_5\text{N}_2\text{H}_3$	22.1	36.3

Pairs of these may be used if it appears that temperature control can be enhanced in this way. If aluminum is not suitable for the casing, non-magnetic stainless steel will be used.

C. Final flight chamber design and construction

D. Attachment of flight chamber to heat sinks

1. Material - (fiberglass in resin)

- a. Temperature tolerance
 - b. Insulating properties
 - c. Mechanical properties
- 2. Method of attachment
- E. Attachment of heat sink to experimental tray
- F. Testing of structural integrity and reliability

PRELAUNCH SCHEDULE

1 April 1979 - 31 June 1979

- A. Experimental colonies
 - 1. Start 10 isolates from each selected strain or species
 - 2. Select six best isolates of the ten for each strain or species
 - 3. At random select two isolates of each strain or species, for flight chambers. Maintain the other four for normal laboratory rearing as laboratory control with replicates.
 - 4. Place cultures in open flight chambers and allow to reach equilibrium with desired humidity
 - 5. Seal and introduce atmosphere into flight chambers. Take to launch site.
 - 6. Select one of each pair at random for flight and insert in experiment tray
 - 7. Return other chambers to laboratory as flight controls
- B. Flight chambers
 - 1. See 4 above
 - 2. Load absorbent sinks and weigh; then 5 above
 - 3. Attach to heat sink fittings
- C. Heat sinks

1. Insert flight chambers
 2. Attach experiment package to experimental tray
- D. Temperature
1. Ambient temperature 21°C to be maintained at launch site

FLIGHT RESEARCH SCHEDULE

1 July 1979 - 1 January 1980

- A. Replicated laboratory controls (A-3 of Prelaunch Schedule)
1. Open pouches as generations approach significant numbers
 2. Make a census of all instars
 3. Determine variability of each instar
 4. Assess results in terms of selective pressures imposed by pouches, e.g., larval sieve
- B. Flight chamber control
1. Store in 25°C refrigerated incubator with horizontal orientation of flight chambers

RECOVERY RESEARCH SCHEDULE

January 1980

- A. Re-entry is desired from dark side of Earth so that maximum amount of heat is dissipated and heat sink is primarily in solid phase prior to re-entry
- B. Inspection of heat sink
1. Integrity of metal
 2. Integrity of phase change material
- C. Return to Acarology Laboratory
1. Flight chambers at $25 \pm 5^\circ\text{C}$ or

2. Flight chambers picked up by personnel of Acarology Laboratory in air-conditioned car
- D. Opening of flight chambers, orbited and unorbited
1. Remove gas sample and analyze for CO₂ and O₂
 2. Weigh carbon sink
 3. Weigh water sink
 4. Check high and low temperature indicators
 5. Open and collect mites from all pouches
 6. Examine compartments as opened for extent of consolidation, of food and nature of attachment of quiescent forms
 7. Prepare cultures of most recent generation for each species/strain
 8. Preserve other generations: 1. the majority in 75% alcohol; 2. at least 300 individuals from each compartment for possible EM study of the fine structure of suspected subcellular modifications

POST-FLIGHT RESEARCH SCHEDULE

January 1980 - 30 June 1981

- A. Live mites, orbited, unorbited, and laboratory controls
1. Observe geotactic responses
 2. Observe other tactile and motor responses
 3. Compare geotaxis using composite scoring method of Hirsch and by analysis of variance
 4. Determine dry weight and water content above CEA
 5. Investigate density dependent population regulating mechanisms of orbited mites
 6. Preserve final flight generation and matching control generations
- B. Preserved mites

1. Census by instar, by compartment, assess population structure (Howe 1975)
 2. Prepare slides for morphological studies of adults of final orbital and nonorbital generations
 3. SEM studies of podocephalic canal of females
 4. Assess for significant deviations from conditions observed for laboratory control during in-flight period
 5. Compare development of significant differences observed by analysis of specimens from each compartment
- C. Preparation of report
1. Introduction
 - a. Currently accepted understanding of biological impact of weightlessness
 - b. Review of original objectives
 - c. Review of geotaxis in Acari
 2. Materials and methods
 - a. Experimental apparatus
 - i. Heat sinks
 - ii. Flight chamber
 - iii. Culture pouches
 - iv. Temperature indicators
 - b. Biological materials
 - i. Species/strains
 - ii. Food
 - c. Experimental design
 - d. Observational techniques
 - e. Statistical analysis
 3. Results

4. Discussion

a. Effects of weightlessness

- i. Sensory deprivation
- ii. Selection for increased tactile sensory input
- iii. Analysis of morphological variation expected to have increased or become directionalized as a result of the absence of gravity as a selective force
- iv. Development of holdfast organs and copulatory structures
- v. Explanation of results

b. General biological applicability of above interpretations

c. Value of results for planning space-based ecosystems

d. Value of results for application to terrestrial problems

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Wrobel, J. R. and Dodds, G. E. 1973. A study of biological experiments for the long duration exposure facility. NAS1-11649.

Appendix B - Scientific Personnel

CURRICULUM VITAE

NAME: G. W. Wharton

TITLE: Professor & Director, Acarology Laboratory

BIRTHDATE: [REDACTED]

PLACE OF BIRTH: [REDACTED]

NATIONALITY: U.S.A.

SEX: Male

EDUCATION: Ph.D. 1939 Zoology - Duke University, Durham, NC

B.Sc. 1935 Zoology - Duke University, Durham, NC

HONORS: Sigma Xi

Phi Beta Kappa

Guggenheim Fellow

Fellow AAAS

Honorary Life Member, International Congress of Acarology

Past President: Society of Systematic Zoology

International Congress of Acarology

Past Council Member: AAAS

American Society of Parasitology

NIAID

Society of Systematic Zoology

MAJOR RESEARCH INTERESTS: Water balance, Acarology

ROLE IN PROPOSED PROJECT: Principal Investigator

RESEARCH AND PROFESSIONAL EXPERIENCE:

1968 - date Professor & Director, Acarology Laboratory
Ohio State University

1961 - 1967 Professor & Chairman, Zoology and Entomology
Ohio State University

1953 - 1961 Professor & Head, Zoology, University of Maryland

1939 - 1953 Instructor, Associate Professor, Duke University

LIST OF PUBLICATIONS (by G. W. Wharton):

1. A. S. Pearse, Marguerite T. Patterson, John S. Rankin and G. W. Wharton. 1936. The ecology of Passalus cornutus Fabricius, a beetle which lives in rotting logs. Ecol. Mono. 6: 455-490.
2. A. S. Pearse and _____. 1938. The oyster "leech" Stylochus inimicus Palombi, associated with oysters on the coasts of Florida. Ecol. Mono. 8: 605-655.
3. _____. 1938. Acarina of Yucatan caves. Carnegie Institution of

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4. _____. 1939. Studies on Lophotaspis vallei (Stossich 1899) (Trematoda: Aspidogastridae). Jour. of Parasitol. 25: 83-86.
5. _____. 1940. The genera Telorchis, Protenes, and Auridistomum (Trematoda: Reneferidae). Jour. of Parasit. 26: 497-518.
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9. _____. 1945. Trombicula frittsi n. sp. (Acarinida: Trombiculidae). Jour. of Parasit. 31: 282-293.
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19. _____. 1948. Four new Peruvian chiggers (Acarina: Trombiculidae). *Psyche*. 55: 87-100.
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21. Charles E. Farrell and _____. 1949. A culture medium for chiggers (Trombiculidae). *Jour. Parasit.* 35: 435.
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- behavior of the snake mite, Ophionyssus natricis (Gervais) (Acarina: Macronyssidae)" by J. Camin, "Ticks (Ixodoidea) of the malagasy faunal region (Excepting the Seychelles)" by Harry Hoogstraal, and "The trombiculid mites of Japan" by Manabu Sasa and E. W. Jameson, Jr. Quarterly Rev. Biol. 29(4): 375.
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- (Acarina: Mesostigmata) parasitic on bats." Jour. of Parasit. 53(6): 1302.
100. _____ and T. L. Devine. 1968. Exchange of water between a mite, Laelaps echidnina, and the surrounding air under equilibrium conditions. Jour. of Insect Physiol. 14: 1303-1318.
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CURRICULUM VITAE

NAME: Dana L. Wrench

TITLE: Research Associate

BIRTHDATE: [REDACTED]

PLACE OF BIRTH: [REDACTED]

NATIONALITY: U.S.A.

SEX: Female

EDUCATION: - Ph.D. 1972 Genetics - The Ohio State University,
Columbus, Ohio

M.Sc. 1970 Genetics - The Ohio State University,
Columbus, Ohio

B.Sc. 1968 Zoology - The Ohio State University,
Columbus, Ohio

HONORS: Woodrow Wilson Fellowship, Honorable Mention
Four-year University Fellowship (Ohio State University)
Sigma Xi

MAJOR RESEARCH INTERESTS: Population biology and genetics

ROLE IN PROPOSED PROJECT: Co-Investigator

RESEARCH AND PROFESSIONAL EXPERIENCE:

1976 - date Research Associate, Ohio State University Research
Foundation

1972 - 1975 NIH Postdoctoral Trainee, Acarology Laboratory, Ohio
State University

1974 (Fall) Visiting Investigator, University of Lund, Lund, Sweden

1972 - 1973 Consultant, IBP Grasslands Biome
(Summer)

1969 - 1971 Graduate Research Assistant and Teaching Associate,
Genetics, Ohio State University

PUBLICATIONS:

1970 The effects of genetic background and temperature on expression
of homozygous cubitus interruptus in eight selection lines of
Drosophila melanogaster. M.Sc. Thesis, The Ohio State
University, 79 + v.

1970 An analysis of penetrance and expressivity in homozygous ci
lines of Drosophila melanogaster selected for the degree of
interruption of the fourth vein. Amer. Zool. 10(4): 353
(with Verl L. House).

- 1972 Autosomal modification of the expression of the cubitus interruptus mutant in Drosophila melanogaster with special reference to phenotypic instability characterizing certain chromosome combinations. Ph.D. Dissertation, The Ohio State University, 158 + xi.
- 1972 The chromosomal basis for differences between two strains of Drosophila melanogaster selected for minimal and maximal expression of the cubitus interruptus gene. Genetics 71 (Supplement): 514-515 (with Verl L. House).
- 1972 Instability in laboratory stocks of Drosophila melanogaster carrying different autosomal modifiers of the cubitus interruptus gene. Amer. Zool. 12: 710-711 (with Verl L. House).
- 1973 Variability in ci expression among lines reconstituted from stocks possessing mixed autosomal modifiers from low and intermediate penetrant selection lines. Genetics 71 (Supplement): 120 (with Verl L. House).
- 1972 Reproduction and habitat in the plains prickly pear (Opuntia polyacantha Haw). Report, I.B.P. Grasslands Biome, Fort Collins, Colorado.
- 1975 Effects of quality of resource and fertilization status on some fitness traits in the two-spotted spider mite, Tetranychus urticae Koch. Oecologia 18: 259-267 (with S. S. Y. Young).
- 1975 Faunal observations on mites of the family Eviphididae in Scandinavia. Entomologen: accepted for publication (with D. E. Johnston).
- 1975 Uroiphicheles landini, a new genus and species of Eviphididae from Sweden. Ent. Scand.: accepted for publication (with D. E. Johnston).
- 1976 Size and natural selection in the hollyhock weevil. (manuscript in preparation) (with D. E. Johnston).
- 1976 The effects of quality of resource and mite density on developmental rate and sex ratio in Tetranychus urticae Koch. (manuscript in preparation) (with S. S. Y. Young).
- 1976 Acarologists of the World - A directory. (in press) (with D. E. Johnston).
- 1976 Guarding, aggressive behavior, and mating success in male two-spotted spider mites. Ann. Entomol. Soc. Amer.: in press (with D. A. Potter and D. E. Johnston).

- 1976 Aggression and mating success in male spider mites. Science: in press (with D. A. Potter and D. E. Johnston).
- 1976 Variegated progeny from a variegated giant ragweed, Ambrosia trifida L. (manuscript in preparation) (with E. F. Paddock).
- 1976 Changes in genotype frequency for two loci of Datura stramonium. (manuscript in preparation) (with E. F. Paddock).
- 1976 Multivariate character analysis in deutonymphs of the family Parasitidae. (manuscript in preparation) (with D. E. Johnston).
- 1976 Contribution of differing character sets to classification of Parasitidae. (manuscript in preparation) (with D. E. Johnston).
- 1976 A numerical taxonomic study of the deutonymphs of the family Parasitidae. (manuscript in preparation) (with D. E. Johnston).

CURRICULUM VITAE

NAME: Francis Alfred Kulacki

TITLE: Associate Professor, Department of Mechanical Engineering

BIRTHDATE: [REDACTED]

PLACE OF BIRTH: [REDACTED]

NATIONALITY: U.S.A..

SEX: Male

EDUCATION: Ph.D. 1971 Mechanical Engineering - University of
Minnesota, Minneapolis, MN
M.Sc. 1966 Gas Technology - Illinois Institute of
Technology, Chicago, IL
B.Sc. 1963 Mechanical Engineering - Illinois Institute of
Technology, Chicago, IL

HONORS: NSF Traineeship (University of Minnesota)
Stan Lensy Scholarship of the Kosciuszko Foundation
(University of Minnesota)
Institute of Gas Technology Fellowship (IIT).
Baltimore Gas and Electric Company Scholarship to IIT
Who's Who in American Colleges and Universities (1963)
Sigma Xi
Tau Beta Pi
Pi Tau Sigma
Texnikoi, Honorary Member

MAJOR RESEARCH INTEREST: Heat transfer

ROLE IN PROPOSED PROJECT: Co-Investigator

RESEARCH AND PROFESSIONAL EXPERIENCE:

1975 - date	Associate Professor, Mechanical Engineering, Ohio State University
1971 - 1975	Assistant Professor, Mechanical Engineering, Ohio State University
1966 - 1971	Research Assistant & Teaching Associate, Mechanical Engineering, University of Minnesota, Minneapolis
1966 (Summer)	Temporary Engineer, Institute of Gas Technology, Chicago
1963 - 1966	Graduate Fellow & Research Assistant, Institute of Gas Technology, Chicago
1963 (Jan.)	Temporary Engineering Personnel, Illinois Institute of Technology Research Instruments, Chicago
1960 - 1963 (Summers)	Junior Engineer, Gas Division, Baltimore Gas & Electric Company, Baltimore

PUBLICATIONS:

1. Theses -

Catalytic Combustion in a Flat Rectangular Channel, MSc thesis, Illinois Institute of Technology, June 1966.

Thermal Convection in a Horizontal Fluid Layer with Uniform Volumetric Energy Sources, PhD thesis, University of Minnesota, December 1971.

2. Papers -

1. Kulacki, F. A., and Gidaspow, D., "Convective Diffusion in a Parallel Plate Duct with One Catalytic Wall - Laminar Flow - First Order Reaction, Part II: Experimental," Canad. J. Chem. Engrg., 45, 74-78, April 1967.
2. Kulacki, F. A., Gidaspow, D., and Solbrig, C. W., "Analysis of Nth Order Reaction Rate Data Using Mixing Cup Charts," Proceedings, XXXVI Congress Internationale de Chime Industrielle, Burssels, September 10-21, 1966.
3. Kulacki, F. A., and Goldstein, R. J., "Thermal Convection in a Horizontal Fluid Layer with Uniform Volumetric Energy Sources," J. Fluid Mech., 55, 271, 1972.
4. Kulacki, F. A., and Goldstein, R. J., "Eddy Heat Transport in Thermal Convection with Volumetric Energy Sources," Paper NC 2.6, Proceedings, Fifth International Heat Transfer Conference, Tokyo, Japan, September 3-7, 1974.
5. Kulacki, F. A. and Goldstein, R. J., "Hydrodynamic Stability in Fluid Layers with Volumetric Energy Sources," Applied Sci. Res., 31, 81 (1975).
6. Kulacki, F. A., and Nagle, M. E., "Natural Convection in a Horizontal Fluid Layer with Volumetric Energy Sources," J. Heat Trans., 97C, 204-211, 1975.
7. Reif, T. H., Nerem, R. M., and Kulacki, F. A., "An In Vitro Study of Transendothelial Albumin Transport in a Steady State Pipe Flow at High Shear Rates," Advances in Engineering, eds. J. A. Brighton and S. Goldstein, 160-161, ASME, New York, 1974.
8. Kulacki, F. A., and Ramchandani, R., "Hydrodynamic Stability in a Porous Layer Saturated with a Heat Generating Fluid," Warme-Und Stoffubertragung, 8, 179-185 (1975).
9. Reif, T. H., Nerem, R. M., and Kulacki, F. A., "An In Vitro

Study of Transendothelial Albumin Transport in a Steady State Pipe Flow at High Shear Rates," to be published in J. Fluids Engng., 1975 (in press).

10. Kulacki, F. A., Emara, A. A., and Min, J. H., "Natural Convection in Internally Heated Fluid Layers - PAHR Applications," Proceedings, Post Accident Heat Removal Information Exchange Meeting, Sandia Laboratories, Albuquerque, New Mexico, November 13-14, 1975.
11. Kulacki, F. A., and Emara, A. A., "Heat Transfer Correlations for Use in PAHR Analysis and Design," Trans., American Nuclear Society, Vol. 22, pgs 447-448, November, 1975.
12. Baker, L., Faw, R. E., and Kulacki, F. A., "Post Accident Heat Removal I: Heat Transfer Within an Internally Heated Non-Boiling Liquid Layer," Submitted to J. Nuc. Sci. Tech., November, 1975 (in process).

3. Technical Reports -

1. Kulacki, F. A., Nagle, M. E., and Cassen, P., "Studies of Heat Source Driven Natural Convection," The Ohio State University Research Foundation, RF-3746, Technical Report 3746-1, July 1974.
2. Kulacki, F. A., and Daubenmier, J. A., "Experiments on Coupled Heat and Mass Transfer in the Presence of an Electrostatic Field," The Ohio State University Engineering Experiment Station, Project EES 439X, Technical Report No.1, July 1974.
3. Kulacki, F. A., and Kevra, J. M., "Coupled Heat and Mass Transfer in the Presence of an Electrostatic Field," The Ohio State University Engineering Experiment Station, Project EES 439X, Technical Report No. 2, July 1975.
4. Kulacki, F. A., and Emara, A. A., "High Rayleigh Number Free Convection in Enclosed Fluid Layers with Internal Heat Sources," The Ohio State University Research Foundation, RF-3746, Technical Report 3952-1, July, 1975; also published by the United States Nuclear Regulatory Commission, Report No. NUREG 75/065, July, 1975.
5. Kulacki, F. A., and Emara, A. A., "Studies of Heat Source Driven Natural Convection," The Ohio State University Research Foundation, RF-3746, Technical Report 3746-2, November, 1975.

Appendix A: Research Prospectuses Submitted in the OSU Program

RESEARCH PROSPECTUS

for the

NASA Long Duration Exposure Facility (LDEF) Program

1. TITLE: Social Behavior of Honey Bees in the Absence of Gravitational Force

2. NAME: John D. Briggs CAMPUS PHONE: 422-1085

CAMPUS ADDRESS: Department of Entomology

1735 Neil Avenue, Columbus, Ohio 43210

3. RESEARCH OBJECTIVES

To detect and investigate (a) the results of the social behavior of an animal colony and (b) the growth and development of individuals and the colony, both (a) and (b) in the absence of gravitational force.

4. JUSTIFICATION

The honey bee provides the unique opportunity to investigate the absence of gravitational force on the genetically determined social behavior in the life of individual animals and a functioning colony unit. Bees care for immatures and other adults in a manner to assure colony success.

5. GENERAL DESCRIPTION

a) Experimental Plan -

Using selfcontained colony units comprising approximately 500 individuals each, the success of development and growth of individual bees and growth of each colony will be measured. The observations at the termination of the weightless period will be made on the forms (eggs, larve, pupae, adults) size, and number of individuals in a colony unit which have resulted from individuals initially introduced into each unit and as a result of egg laying by the inseminated queen accompanying each colony unit. Matched duplicate units will be maintained in a station at the University.

b) Experimental Apparatus -

Apparatus will comprise ten closed units of dimensions to occupy at total of ten cubic feet, sealed before launch. Food in solid form, and water in a pressurized demand system will be adequate

for the full period of the exposure. The colony units will utilize the air supply to be designed. See attached sheet for air volume requirements.

c) Special or Unusual Design Requirements -

- (a) Insect-tight units with adequate gas exchange
- (b) Food and moisture source compatible with loss of gravitational force
- (c) Provision of plastic (flexible) enclosure similar to gnotobiotic units for all ten colony units.

6. WHAT NEEDS TO BE DONE TO FURTHER DEVELOP YOUR RESEARCH IDEA INTO A MORE DETAILED PRELIMINARY PROPOSAL?

- (a) Complete the identification of model colony units for accommodation in LDEF with respect to size and food/water supplies.
- (b) Provide drawings and illustrations to support proposal.
- (c) Complete statistical design for evaluation of data.

7. FUNDING REQUIREMENTS TO DEVELOP A MORE DETAILED PROPOSAL

(Please include salaries and wages and other miscellaneous expenses)

Salaries:	\$2130
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Construction of models of 30 day colony units	300
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Total	\$2430
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Attachment: Gas Use for Honey Bee Experiment in LDEF

- (a) Average O_2 rate: $1.0 \text{ mm}^3/\text{mg-live wt/hr.}$
- (b) O_2 consumption at
1.0 atm for maximum
of 3000 bees: $5 \times 10^5 \text{ mm}^3/\text{hr}$
- (c) $1.0 \text{ M}^3 O_2$ will be consumed in 2000 hrs.
 $1.5 \text{ M}^3 O_2$ will be consumed in 3000 hrs. (expected duration of experiment)
- (d) Providing a safety factor of 2, $30. \text{ M}^3 O_2$ will be consumed in 3000 hrs.

- (e) To provide $3.0 \text{ M}^3 \text{ O}_2$ in a 60/40 (O_2/N_2) mixture, the total volume of gas to be needed at 1:0 atm to the bees should be 5.0 M^3 .
- (f) The gas can be compressed to a practical volume for use in LDEF

RESEARCH PROSPECTUS

for the

NASA Long Duration Exposure Facility (LDEF) Program

1. TITLE: Inducibility of prophage in *Escherichia coli* and *Mycobacterium butyricum* in space environment

2. NAME: Bernard U. Bowman, Jr., Ph.D. CAMPUS PHONE: 422-5772

CAMPUS ADDRESS: 2194 Graves Hall, Department of Medical Microbiology

333 West Tenth Avenue, Columbus, Ohio 43210

3. RESEARCH OBJECTIVES

To determine if natural forces (radiation, vacuum, no gravity) of space environment will act as inducer of prophage(s) for their development into vegetative phage with subsequent phage production. The absence or presence of phage induction will be compared to that obtainable on earth by heat or ultraviolet (UV) light treatments.

4. JUSTIFICATION

The proportion of lysogenic cells inducible with UV light on earth falls into three categories: (A) cells such as *E. coli* (λ) - approximately 100 per cent; (B) cells of *E. coli* (PT) - about 10 percent; and (C) cells of *M. butyricum* (R1); about 0.01 percent. Since the effect of space environment on inducibility is not known for these systems, any new information obtainable on induction in these systems would be valuable. In addition to obtaining basic biological information, new insights into mechanisms of genetic integration of animal [human] and viral DNA should be gained, which might be applied to virus induced tumors. Particular emphasis would be applied to obtaining an understanding of mechanisms of virus excision from host DNA. Comparison of the low-efficiency inducing system [*M. butyricum* (R1)] with the high efficiency system [*E. coli* (λ)] might provide information of differences in mechanisms of control which could be extrapolated to animal virus-host relationships. In addition, the choice of the *M. butyricum* (R1) system may have advantage over the *E. coli* phage systems, since the former could be expected to survive for a month or more due to its longer generation time than the latter.

5. GENERAL DESCRIPTION

a) Experimental Plan - For exposure to space environment in the

LDEF, the following would be prepared:

- 1) Broth and agar slant cultures of each of the lysogenic systems.
- 2) For controls, broth and agar slant cultures of each of the strains - but not lysogenic (not carrying prophage).
- 3) Suspensions of purified phage of each that is carried as prophage in lysogenic cells.
- 4) If obtainable, purified solutions of specific repressor protein for each phage. [This substance is known to maintain lysogeny in *E. coli* (λ).] These materials would be placed in LDEF and submitted to space environment for variable periods of time.

Upon return to earth, the materials would be collected, suitably preserved, and assayed for the following:

- a) Proportion of lysogenic cells induced.
- b) Number of cells killed as colony-formers.
- c) Amount of phage produced as a result of induction.
- d) Activity of repressor protein.
- e) Proportion of free phage inactivated.

The results would be compared to that obtainable with similarly prepared bacteria, and repressor protein treated with UV light or heat on earth.

b) Experimental Apparatus -

Sterile, non-radiation absorbing tubes or vials to contain biological products.

c) Special or Unusual Design Requirements -

None

6. WHAT NEEDS TO BE DONE TO FURTHER DEVELOP YOUR RESEARCH IDEA INTO A MORE DETAILED PRELIMINARY PROPOSAL?

To investigate cells of *M. butyricum* (R1) for the presence of repressor protein.

To do a complete literature search to determine the extent of work already done or overlap with other systems.

7. FUNDING REQUIREMENTS TO DEVELOP A MORE DETAILED PROPOSAL: (Please include salaries and wages and other miscellaneous expenses)?

\$5,000 to initiate studies on M. butyricum (R1) for demonstration and isolation of repressor protein.

RESEARCH PROSPECTUS

for the

NASA Long Duration Exposure Facility (LDEF) Program

1. TITLE: Effect of space environment on bacteria and viruses:

Lethality, mutagenesis, and induction of lysogens

2. NAME: Bernard U. Bowman, Ph.D. CAMPUS PHONE: 422-5772

CAMPUS ADDRESS: Department of Medical Microbiology, 2194 Graves

Hall, 333 West Tenth Avenue, Columbus, Ohio 43210

3. RESEARCH OBJECTIVES

The research objectives are to determine some of the effects of natural forces of space environment on bacteria and on viruses. Parameters of the effect of the environment that will be investigated are (1) lethality to bacteria and to viruses; (2) induction of mutation in bacteria; and (3) induction of lysogenic bacteria.

4. JUSTIFICATION

The justification of the proposed research is to obtain information on the effect of space environment on specific slow growing and fast growing bacterial cells and specific viruses for the purpose of possibly extrapolating this knowledge to eucaryotic cells and higher forms of life. The comparison of the effects between slow growing and fast growing bacterial cells is viewed to be an aid in extrapolating results to higher life forms.

5. GENERAL DESCRIPTION

a) Experimental Plan -

Lethality of Space Environment

Bacteria: Since bacterial cells have varying rates of cell division, slow growing (Mycobacterium avium) and fast growing (Escherichia coli) bacteria will be exposed to space environment in a suitable medium. After exposure of both liquid and agar cultures of each organism, bacterial assays will be performed to determine the number of survivors. For controls, cultures of both species, grown similarly on earth and at the same fluctuating temperatures (0°C to 40°C) of space environment, will be assayed for total bacteria. In addition, another control will be comprised of similar bacterial preparations as used in

space, but will be irradiated with different doses of artificially produced ultraviolet light on earth at temperatures between 0°C and 40°C, and assayed for surviving bacteria.

Viruses (Bacteriophages): M. butyricum (R1) produces a temperate phage called R1 and E. coli (λ) produces temperate phage λ . Each of these phages in highly purified preparations will be subjected to the space environment to determine their stability. For this purpose, both phages at concentrations ranging between 10^{12} and 10^6 plaque-forming units/ml (one plaque-forming unit is equivalent to one virus particle) in suitable medium and containers will be exposed to the space environment and upon return to earth assayed for plaque formers. Both of these phages are DNA-containing phages and can be expected to be inactivated in the space environment, but of course the extent of inactivation is unknown. For controls, similar suspensions will be prepared and irradiated with various doses of artificially produced ultraviolet light, on earth; at temperatures between 0°C and 40°C, and assayed for surviving phages. Another control will be similar suspensions of these phages held at 4°C, on earth, and not exposed to ultraviolet light.

Induction of Bacterial Mutants: Bacteria surviving exposure to space environment will be isolated, cultured, and tested for various mutations. For example, tests for mutations such as colonial morphology changes, drug resistance, ultraviolet light resistance, and phage resistance will be performed. For controls, bacteria treated (and untreated) with ultraviolet light on earth will be assayed for mutations similarly.

Induction of Lysogenic bacteria: Certain lysogenic bacteria produce bacteriophage spontaneously. Ultraviolet light treatment and X-irradiation treatment of these same lysogenic bacteria increase the proportion of cells in a population able to produce phage and this is called induction. Furthermore, some lysogenic bacteria, such as E. coli (λ), can be almost completely induced by ultraviolet light, that is, almost every cell in a population will produce phage. Other lysogenic bacteria, M. butyricum (R1), for example, has a limited ultraviolet light induction efficiency of only about $1/10^4$ cells in a population and a spontaneous induction of about $1/10^6$ cells. Comparison of the low-efficiency inducing system [M. butyricum (R1)] with the high-efficiency system [E. coli (λ)] after exposure to space environment might provide more information on control of induction which could be extended to animal virus-host relationships.

The general experimental plan is to prepare liquid and agar cultures of both E. coli (λ) and M. butyricum (R1) in suitable broth and containers, expose them to the space environment and determine the proportion of lysogenic cells induced. This determination would be done by performing bacterial assays for surviving bacteria (since all induced bacteria are inactivated as colony formers). The control would be nonlysogenic bacteria treated in a similar fashion. An alternative

method will be used in which lyophilized lysogenic cells, either in the dry state or suspended in saline, are exposed to the space environment, and upon return to earth, assayed for infectious centers. This assay registers plaques from intracellular developing phage. Therefore, any plaques obtained would derive from induction of a lysogenic cell. The overall control will be exposure of similar lysogenic cells to various doses of artificially produced ultraviolet light on earth at temperatures between 0°C and 40°C.

b) Experimental Apparatus -

Sterile, non-radiation absorbing tubes or vials to contain biological preparations.

c) Special or Unusual Design Requirements -

None

6. WHAT NEEDS TO BE DONE TO FURTHER DEVELOP YOUR RESEARCH IDEA INTO A MORE DETAILED PRELIMINARY PROPOSAL?

- 1) Preparation of adequate amounts of highly purified R1 and λ bacteriophages.
- 2) Preparation of cultures of the various bacterial for exposure to space environment.
- 3) Development of techniques to determine the number of cells induced (by ultraviolet light) in lyophilized preparations of lysogenic bacteria.
- 4) Development of techniques for assaying for bacterial mutants.
- 5) To do a complete literature search to determine the extent of work already done or overlap with other systems.
- 6) To visit a bacteriology section of a "Space laboratory" to learn techniques of which I am not familiar.

7. FUNDING REQUIREMENTS TO DEVELOP A MORE DETAILED PROPOSAL:
(Please include salaries and wages and other miscellaneous expenses):

Graduate student stipend	\$2,500
Material and supplies	2,000
Travel (visit to "Space lab" to learn new techniques)	500
	<hr/> \$5,000

RESEARCH PROSPECTUS

for the

NASA Long Duration Exposure Facility (LDEF) Program

1. TITLE: Earth's Shape and Surface Features from LDEF

2. NAME: Sanjib K. Ghosh CAMPUS PHONE: 2-5720, 6753

CAMPUS ADDRESS: Department of Geodetic Science, 325 Cockins Hall
1958 Neil Avenue, Columbus, Ohio, 43210

3. RESEARCH OBJECTIVES

To provide more comprehensive data than heretofore available on the surface features and shape of the earth (in the tropical areas). Preliminary research to assess the outfit for eventual selection before used on LDEF.

4. JUSTIFICATION

For developing and utilizing the procedures of quantitative mapping of the earth (surface interpretations and mensurations) in a broad scale. To check for seasonal dimensional changes, if any, in view of possible space environment effects.

5. GENERAL DESCRIPTION

a) Experimental Plan -

The outfit (sensors) are: Radar Altimeter or Airborne Profile recorder (APR) and a Photogrammetric Camera (preferably of long focal length). The sensors are to be placed such that their axes are parallel to the axis of the LDEF, and, accordingly, directed to the center of mass of the earth. These would provide, apart from photographic data, ground clearance of the LDEF and surface scattering. These will establish ground profiles of the tracks of the LDEF. An integration (easily possible with abundance of data) of such profiles will help in mapping the ground and establishing the shape of the earth (over the ground and water, both) with such data as are independent of gravity in a first-order sense. Modern geodetic-photogrammetric-remote sensing techniques with computer assisted solutions will be used.

The LDEF being a reusable, low cost, free flying, low-orbit and with attitude control (configured for gravity-gradient stabilization) is uniquely suited for such research investigations, which were virtually impossible with other previous satellites.

b) Experimental Apparatus -

- 1) Radar Altimeter (RA) or Airborne Profile Recorder (APR)
- 2) Photogrammetric Camera (with retrievable film)

It is desired to use correlative data obtained from the above mentioned equipment.

c) Special or Unusual Design Requirements -

Based on the analogies pursued in remote sensing (data procurement) procedure, some computer generated simulations may be necessary to handle information on topocentric radial distances of ground points (along tracks -- profiles). Expecting continuous trackings, such profiles (obtained from RA or APR), when integrated, will help us determine the ground (and water) shape of the earth. The stereophoto coverage will provide checks and additional information to establish them with such data as are independent of gravity in a first order sense.

6. WHAT NEEDS TO BE DONE TO FURTHER DEVELOP YOUR RESEARCH IDEA INTO A MORE DETAILED PRELIMINARY PROPOSAL?

Literature search.

Some investigative research to pick up the best available equipment and establish a sound approach.

7. FUNDING REQUIREMENTS TO DEVELOP A MORE DETAILED PROPOSAL
(Please include salaries and wages and other miscellaneous expenses):

Graduate Research Associate, Nine months @ \$400/mo.	\$3600.00
Miscellaneous	
Xeroxing, Telephone calls, Postage, Typing, etc.	200.00
Total	<hr/> \$3800.00

RESEARCH PROSPECTUS

for the

NASA Long Duration Exposure Facility (LDEF) Program

1. TITLE: Natural Convection in a Low Gravity Environment:
Investigation of Wall Boundary Layers
2. NAME: F. A. Kulacki CAMPUS PHONE: 422-6676
CAMPUS ADDRESS: Department of Mechanical Engineering
206 West 18th Avenue, Columbus, Ohio, 43210

3. RESEARCH OBJECTIVES

To provide definitive and accurate data on low Grashoff number natural convection and convection instability that cannot be obtained from earthbound experiments on systems wherein wall boundary layers are present.

4. JUSTIFICATION

For determining leading edge heat transfer and heat transfer where the thin boundary layer assumptions do not apply; for assessment of Prandtl number effects on heat transfer in the zero gravity environment; and for determination of transient heat transfer and boundary layer development in the zero gravity environment. This information will be applicable to design and manufacturing processes in reduced gravity environment.

5. GENERAL DESCRIPTION

a) Experimental Plan -

Apparatus to be flown into orbit and thermally stabilized to an isothermal condition. Small heaters in the heat transfer surface(s) will initiate experimental runs. Heat-up and cool-down runs to continue until battery power is exhausted or indefinitely in event solar heating is used. Data to be recorded on magnetic tape.

b) Experimental Apparatus -

Convection apparatus to comprise flat plates or cylinders heated electrically or by solar energy delivered via heat pipes. Relatively large size (e.g., 2 in. dia. cylinder) test areas will

be used, and test surface and local fluid environment will be contained in a thermally controlled envelope. Instrumentation will consist of heat flux meters, thermocouples, etc., whose outputs will be recorded on tape. Steady and transient runs to be controlled with preprogrammed timer and feedback control systems.

c) Special or Unusual Design Requirements -

Will need to develop appropriate batteries or have apparatus located on LDEF close to outer surface. Test surfaces will have to be aligned parallel to weak gravity field which may be present in the near-earth orbit.

6. WHAT NEEDS TO BE DONE TO FURTHER DEVELOP YOUR RESEARCH IDEA INTO A MORE DETAILED PRELIMINARY PROPOSAL?

Engineering design calculations will be needed to determine appropriate scale for the test surface relative to the fluid volume. Computer code must be developed to study the flow regimes expected in a relatively confined environment and to determine which portion of the experimental data will be relevant to the experimental objectives.

7. FUNDING REQUIREMENTS TO DEVELOP A MORE DETAILED PROPOSAL
(Please include salaries and wages and other miscellaneous expenses):

Salaries	\$2,000
Computer time	1,000
Total	<u>\$3,000</u>

RESEARCH PROSPECTUS
for the
NASA Long Duration Exposure Facility (LDEF) Program

1. TITLE: Natural Convection in a Low Gravity Environment:
Fluid Layers

2. NAME: F. A. Kulacki CAMPUS PHONE: 422-6676
CAMPUS ADDRESS: Department of Mechanical Engineering
206 West 18th Avenue, Columbus, Ohio, 43210

3. RESEARCH OBJECTIVES

To provide definitive and accurate data on low Rayleigh number natural convection and convection instability that cannot be obtained from earth bound experiments.

4. JUSTIFICATION

For verification of predictions of theoretical stability analysis for fluid layers heated from below and for determination of heat transfer coefficients within the layer for low Rayleigh number regimes. This information will be applicable to design and manufacturing processes in reduced gravity environments.

5. GENERAL DESCRIPTION

a) Experimental Plan -

Apparatus to be flown into orbit and thermally stabilized to an isothermal condition. Small heaters in the heat transfer surfaces will initiate experiment by creating temperature differential across the layer. Temperature at mid-plane of layer will be monitored, and, when at steady state, data will be recorded. This type of run will be repeated for several low values of Rayleigh number.

b) Experimental Apparatus -

Apparatus to comprise a thin, enclosed fluid layer across which either a specified temperature drop or a specified heat flux is maintained. Instrumentation will consist of heat flux meters, thermocouples, etc., whose outputs will be continuously

recorded. Experiment control will be provided by a preprogrammed timer which will control power input to layer surfaces.

c) Special or Unusual Design Requirements ~

Need battery power and development of special recording devices for thermocouples, heat flux meters, etc.

6. WHAT NEEDS TO BE DONE TO FURTHER DEVELOP YOUR RESEARCH IDEA INTO A MORE DETAILED PRELIMINARY PROPOSAL?

Engineering calculations to determine experiment scale relative to power availability. A small apparatus will have to be built to test feasibility of design based on calculation.

7. FUNDING REQUIREMENTS TO DEVELOP A MORE DETAILED PROPOSAL.
(Please include salaries and wages and other miscellaneous expenses):

Salaries	\$2,000
Equipment	1,000
Total	<u>\$3,000</u>

RESEARCH PROSPECTUS
for the
NASA Long Duration Exposure Facility (LDEF) Program

1. TITLE: Steady State Boiling Heat Transfer in a Zero Gravity Environment

2. NAME: F. A. Kulacki CAMPUS PHONE: 422-6676
CAMPUS ADDRESS: Department of Mechanical Engineering
206 West 18th Avenue, Columbus, Ohio, 43210

3. RESEARCH OBJECTIVES:

To determine heat transfer correlations for nucleate and film boiling in a zero gravity environment.

4. JUSTIFICATION

All data available at present on boiling heat transfer in reduced gravity has been obtained from drop tower tests of short (1 s or less) duration. Proposed experiments would provide truly steady state heat transfer correlations. Such results will be applicable in space craft heat transfer design where high heat fluxes are needed.

5. GENERAL DESCRIPTION

a) Experimental Plan -

Nucleate and film boiling will be initiated on an electrically heated wire or on a flat strip imbedded in an adiabatic surface. The fluid will be a low boiling-point liquid to lessen total power requirements. Released vapor will be condensed on the boundaries of the container and recycled to the boiling liquid. Appropriate temperatures will be continuously monitored and recorded on tape.

b) Experimental Apparatus -

The heat transfer surface and test liquid will be contained in sealed volume which will be pressurized. Batteries will be the source of power to the heat transfer surface. Total power requirements will be held to a minimum by keeping test surface and liquid volume small.

c) Special or Unusual Design Requirements -

None for the heat transfer apparatus, but some special design effort will have to go into the data recording and power systems.

6. WHAT NEEDS TO BE DONE TO FURTHER DEVELOP YOUR RESEARCH IDEA INTO A MORE DETAILED PRELIMINARY PROPOSAL?

Engineering calculations to determine experiment scale.
Building a small boiler for testing design feasibility.

7. FUNDING REQUIREMENTS TO DEVELOP A MORE DETAILED PROPOSAL
(Please include salaries and wages and other miscellaneous expenses):

Salaries	\$2,000
Equipment	<u>1,000</u>
Total	\$3,000

RESEARCH PROSPECTUS

for the

NASA Long Duration Exposure Facility (LDEF) Program

1. TITLE: Ultra-Pure Germanium Gamma Ray Radiation Detectors
in the Space Environment

2. NAME: D. W. Miller and M. S. Gerber CAMPUS PHONE: 422-7979

CAMPUS ADDRESS: Department of Nuclear Engineering

206 West 18th Avenue, Columbus, Ohio, 43210

3. RESEARCH OBJECTIVES

The general research objective is the evaluation and use of ultra pure (intrinsic) germanium radiation detectors for characterizing gamma ray and high energy x-ray (hereafter referred to as high energy photons) spectral distribution in the space environment. This general objective will be accomplished in the Long Duration Exposure Facility (LDEF) in a twofold manner:

- (1) An active experiment in which an intrinsic germanium detector with associated instrumentation and power supply is used to measure the omnidirectional, time-integrated high energy photon radiation spectrum.
- (2) An evaluation of long-term space-related effects in intrinsic germanium pertinent to high energy photon radiation detection.

4. JUSTIFICATION

The radiation environment in space has long been of interest to the scientist and engineer, and has been the objective of numerous experiments. Photon and ion radiations have been measured using silicon detectors with considerable success. However, silicon radiation detectors are limited in response to predominantly low energy photons and low and high energy ions. This is a consequence of the low Z number of silicon and thus poor stopping power for high energy photons. Germanium detectors, which are currently used to measure medium and high energy (greater than 50 keV) photons, have been restricted in their use in space by the requirement for continual cooling to 77°K. This limitation is a consequence of the use of lithium drifted germanium [Ge(Li)] detectors and is due

to the rapid diffusion of lithium in germanium at ambient temperatures. Recently, with the development of large size intrinsic germanium crystals [1], detectors can be fabricated which are not degraded in performance by wide temperature fluctuations often encountered in space experiments. In addition, unique and useful geometric configurations can be fabricated which will aid in various experiments designed to characterize high energy photon spectra,

The need for detectors to measure photons and other radiations which cannot be detected by silicon detectors is well justified. The requirements which pertain specifically to the Space Shuttle program include both natural background radiation and shuttle induced radiation such as secondary emissions and neutron activation [2].

Based on conversations with scientific staff at Jet Propulsion Laboratory and Goddard Space Flight Laboratory, engineering interest [2] is related to the characterization of the natural background and the shuttle induced radiations in order to improve personnel safety. For example, precision measurements of the photon energy spectra can, through the use of unfolding techniques, lead to improved understanding of both the space radiation environment and to methods for improved shielding and selection of materials for personnel safety.

To attain both the desired scientific and engineering objectives, detectors arranged in clusters and possibly providing spatial information would be desirable [2]. Configurations of this nature are difficult if not impossible to construct using Ge(Li) detectors. However, as shown in recent developments in nuclear medicine [3-6], unique configurations and groups of detectors are feasible using intrinsic germanium detectors.

5. GENERAL DESCRIPTION

a) Experimental Plan

The long-term space induced changes in radiation detection properties of intrinsic germanium detectors will be determined by the measurement of material properties and high energy photon response prior to and subsequent to the long duration space mission. The first objective will be accomplished by the measurement of a number of selected properties related to high energy photon detection. These will include, although will not be restricted to, leakage current, depletion voltage and impurity concentration. The measurements will be made in a well controlled laboratory environment. High energy photon spectra measurements will be made using standardized spectrometer instrumentation. In addition, photon spectra measurements made during the mission will provide data

characterizing the change in detector performance throughout the mission as well as the nature of the space radiation environment.

The measurement of the high energy photon radiations will be performed using the intrinsic germanium detector along with a self-contained electronics package and power supply. The detector and associated electronics will comprise a high energy photon spectrometer which will measure and store energy spectra at specific predetermined time intervals during the experiment.

The detector will be cooled during operation either by a small closed cycle refrigeration unit or a heat pipe connected to the outside of the space vehicle. The closed cycle refrigeration unit may be feasible since cryogenic temperatures are only required during actual operation; thus minimizing power consumption. The cooling of the detector using a small heat pipe may also be possible although operation would be restricted to times when the heat pump connection was away from solar radiation. The heat pipe system would also be designed to prevent overheating of the detector when the pipe is being heated by solar radiation. Since the actual temperature within the vehicle is well controlled ($293 \pm 20\text{K}$) the thermodynamics system design will be considerably simplified.

b) Experimental Apparatus

Laboratory apparatus routinely used in material and detector measurements will be used in the materials measurement phase. Specialized measurements such as impurity concentration will be made under a cooperative arrangement with the intrinsic germanium crystal vendor [1].

Electronic measurement apparatus compatible with the space environment and power and size limitations will be developed in cooperation with one of several companies specializing in space instrumentation.

The principle investigators for the proposed project are familiar with the available capabilities and have experience with all aspects of the measurement apparatus.

c) Specialized or Unusual Design Requirements

1. Low power, self-contained miniature electronic package which will be used with the intrinsic germanium detector and will comprise a high energy photon spectrometer and data storage instrument.

2. Battery power pack compatible with the space and weight requirements, and capable of supplying the required power.
3. Technique for cooling the intrinsic germanium detector during operation.

6. NEEDS FOR COMPLETION OF FINAL PROPOSAL

1. Detailed system design analysis and proposed design must be completed.
2. The specific engineering and scientific objectives of high energy photon measurements must be delineated in order to optimize the detector geometry.
3. The selection of an optimum cooling concept must be made.
4. Tentative cooperative arrangements between The Ohio State University, the germanium vendor and the space instrumentation vendor must be made.

7. FUNDING REQUIREMENTS

Professional Staff Salaries	\$1,500
Graduate Research Associate	1,950
Long Distance Telephone	50
Reproduction	50
Total	<hr/> \$3,550

8. REFERENCES

1. The General Electric Space Technology Division, Philadelphia, Pennsylvania.
2. Scientific Staff, Goddard Space Flight Laboratory and Jet Propulsion Laboratory.
3. D. W. Miller, P. A. Schlosser, M. S. Gerber, R. F. Redmond, W. W. Hunter, Jr., "A Prototype Gamma Camera System Based on a Strip Electrode, High Purity Germanium Detector," Annual Society of Nuclear Medicine Meeting, San Diego, California, June 1974.

4. P. A. Schlosser, M. S. Gerber, D. W. Miller and A. H. Deutchman, "A Large Scale Medical Gamma Camera System Based on Orthogonal Strip, High Purity Germanium Detectors," IEEE Nuclear Science Symposium, Washington, D. C., December 1974.
5. L. Kaufman, G. Armantrout, et al., "Imaging with a Small Ultra-Pure Germanium Gamma Camera," IEEE Trans. Nucl. Sci., NS-21, No. 1, p. 395 (February 1975).
6. M. S. Gerber, D. W. Miller, B. Gillespie and R. S. Chemistruck, "Instrumentation for a High Purity Germanium Position Sensing Gamma Ray Detector," IEEE Trans. Nucl. Sci., NS-22, No. 1, p. 416 (February 1975).

RESEARCH PROSPECTUS
for the
NASA Long Duration Exposure Facility (LDEF) Program

1. TITLE: Effect of Gravity-free Environment on Plant
Embryogenesis
2. NAME: Valayamghat Raghavan CAMPUS PHONE: 2-4723
CAMPUS ADDRESS: Department of Botany
1735 Neil Avenue, Columbus, Ohio, 43210 - . . .

3. RESEARCH OBJECTIVES

To determine whether gravity-free environment has any influence on the organization, growth and development of plant embryos in vitro; to study the effect of gravity on the origin of polarity during embryogenesis in plants.

4. JUSTIFICATION

In both plants and animals, a single-celled zygote is the beginning of operation of a series of subtle and complex influences that result in the formation of an adult organism. Unlike animal systems, techniques have been developed in plants whereby it is possible to remove embryos at an early stage of development from the environment of the ovule and nurture them into full-grown plants. Considerable background information is also available on the effects several plant hormones (such as indoleacetic acid, gibberellic acid, cytokinins, etc.) and the ordinary physical environment such as light quality and duration, gases, etc., on the growth and morphogenesis of embryos in culture, but as far as I am aware, no information is available on the effect of the space environment on the growth of embryos in culture.

The possibility of obtaining adventive embryoids (embryo-like structures which look like zygotic embryos and which regenerate new plants) in quantity from the vegetative organs of plants by relatively simple manipulations provides yet another system to study the effects of the gravity-free environment on embryogenesis. I believe that results from studies using both zygotic embryos and embryoids will provide a firm basis for formulating hypothesis with regard to the hazards of the space-environment

on embryogenesis. Hopefully, this information should help us to regulate embryogenesis and embryonic development in biological organisms in the space to our advantage.

5. GENERAL DESCRIPTION

a) Experimental Plan -

1. Isolation of embryos from plants currently studied in my laboratory (for example, sunflower, tomato) and their culture under aseptic conditions.
2. Production of adventive embryos from such well-investigated systems such as carrot, also studied in my laboratory.
3. Analysis of development of embryos initially on the gravity-free environment of the klinostat.
4. Comparison of the metabolic activity (for example, DNA synthesis, RNA synthesis, protein synthesis) in embryos grown under natural conditions in the laboratory and in the space environment, to determine whether the latter has any effect on the basic macro-molecular synthetic abilities of the embryos.

Both zygotic embryos and embryoids will be used for the experiments.

b) Experimental Apparatus -

Since my laboratory is primarily engaged in tissue culture work, glassware, etc., for the culture of embryos will be available here.

However, we should have a klinostat to do the initial experiments on the effect of gravity-free environment.

c) Special or Unusual Design Requirements -

None

6. WHAT NEEDS TO BE DONE TO FURTHER DEVELOP YOUR RESEARCH IDEA INTO A MORE DETAILED PRELIMINARY PROPOSAL?

We should have enough background information to see whether embryos develop normally or abnormally when they are grown in a gravity-free environment. We should determine how the space environment affects the synthetic abilities of the different cells of the embryo. We should also determine whether adventive embryos (embryoids) react in a similar way as normal zygotic

embryos. This information will be especially helpful since it is easy to obtain the former in quantity for cultural and biochemical studies.

7. FUNDING REQUIREMENTS TO DEVELOP A MORE DETAILED PROPOSAL
(Please include salaries and wages and other miscellaneous expenses):

Graduate research assistant 2 quarters	\$2,400.00
Chemicals and supplies	1,200.00
Klinostat	400.00
	<hr/>
Total	\$4,000.00

RESEARCH PROSPECTUS
for the
NASA Long Duration Exposure Facility (LDEF) Program

1. TITLE: Effect of Zero Gravity on the Growth and Pathogenicity of
Selected Zoopathogenic Fungi

2. NAME: John A. Schmitt CAMPUS PHONE: 422-5504

CAMPUS ADDRESS: Department of Botany
1735 Neil Avenue, Columbus, Ohio, 43210

3. RESEARCH OBJECTIVES

To ascertain the effect of zero gravity on the growth and pathogenicity of Candida albicans (an endogenous human pathogen) and Histoplasma capsulatum (an exogenous human pathogen).

4. JUSTIFICATION

Candida albicans occurs as an oral commensal (potential pathogen) in about 35% of the human population (Schmitt, 1971); any internal or external stressing of the host's system allows the fungus to evoke overt candidiasis. Histoplasma capsulatum causes a primary pulmonary mycosis, especially in compromised individuals.

5. GENERAL DESCRIPTION

a) Experimental Plan -

Expose cultures of each organism of known pathogenicity to LDEF conditions. Upon return, inoculate laboratory mice, using standard methods, with LDEF-grown cultures and earth-grown cultures for comparative pathogenicity studies. Perform comparative light microscopy, transmission electron microscopy and scanning electron microscopy on exposed vs non-exposed cultures. Perform comparative studies of exposed vs non-exposed cultures to evoke immunological responses in rabbits.

This is part of an overall investigation of the interaction between suppression of the human immune system and the ability of C. albicans and other fungi to evoke overt respiratory mycoses. Animal studies will be proposed formally (they have already been suggested to NASA) for one of the short duration, manned flights, due to the necessity for animal care.

b) Experimental Apparatus -

Racks to hold test tube and flask cultures of the two organisms in a humidity cabinet to prevent dessication of the agar media; 37°C incubator for the H. capsulatum cultures; 23 - 25°C incubator for C. albicans.

c) Special or Unusual Design Requirements - None anticipated unless the two incubators will present special difficulties in flight.

6. WHAT NEEDS TO BE DONE TO FURTHER DEVELOP YOUR RESEARCH IDEA INTO A MORE DETAILED PRELIMINARY PROPOSAL?

Feasibility study to determine if it is possible to maintain the organisms in liquid media and/or semi-solid media for six months without subculturing while retaining viability. It might necessitate adaptation of continuous-flow culture techniques to use with these fungi. Other aspects suggested need no special development.

7. FUNDING REQUIREMENTS TO DEVELOP A MORE DETAILED PROPOSAL
(Please include salaries and wages and other miscellaneous expenses):

Graduate Research Associate, 2 quarters, 50% time	\$1,950.00
Growth Media	100.00
Apparatus (Glassware, Incubators, etc.)	1,000.00
Miscellaneous (Postage, telephone calls, etc.)	150.00
Total Requested	<hr/> \$3,200.00

RESEARCH PROSPECTUS
for the
NASA Long Duration Exposure Facility (LDEF) Program

1. TITLE: Importance of Gravity to Survival Strategies of
Small Animals

2. NAME: G. W. Wharton CAMPUS PHONE: 2.7180

CAMPUS ADDRESS: Acarology Laboratory
484 West 12th Avenue, Columbus, Ohio, 43210

3. RESEARCH OBJECTIVES

The static form of living material and changes in form resulting from growth in all cases may be described as due to force (Thompson, 1942, p. 16). I wish to determine if the absence of the force of gravity modifies the development of animals weighing less than 0.0001 g.

4. JUSTIFICATION

Gravity exerts small forces on animals that weigh less than 0.0001 g. Nevertheless, they adapt to gravity by the development of pedal suckers, other holdfast organs, and behavioral responses. Culturing Acari in the absence of gravity will enable the direct influence of gravity on acarine form, if any, to be divorced from its influence through natural selection.

5. GENERAL DESCRIPTION

a) Experimental Plan -

Comparable cultures of two species of mites will be allowed to grow for six months in the laboratory and in space. The cultures will be examined at the end of six months and each specimen will be studied for anatomical modifications. The results of these studies can then be compared to determine whether or not the space and Earth populations are essentially the same in form and numbers of each instar or if not, in what ways they differ.

b) Experimental Apparatus -

An apparatus that provides for maintenance of an ambient

atmosphere of air with a constant humidity of 80% R.H. and a temperature of about $25^{\circ}\text{C} \pm 1^{\circ}$ in a chamber of 0.1 cubic feet would be necessary. Two units, one for space and one for Earth would be needed.

c) Special or Unusual Design Requirements -

No special or unusual design requirements other than the culture chambers are required.

6. WHAT NEEDS TO BE DONE TO FURTHER DEVELOP YOUR RESEARCH IDEA INTO A MORE DETAILED PRELIMINARY PROPOSAL?

Develop plans for: 1) the special apparatus that will serve as a life support system in space, 2) culture vessels that will separate the generations of mites from each other, 3) computer programs for comparing the results of anatomical studies, 4) a bibliography of studies concerning variability accompanying mass cultures of small arthropods.

7. FUNDING REQUIREMENTS TO DEVELOP A MORE DETAILED PROPOSAL
(Please include salaries and wages and other miscellaneous expenses):

Salaries

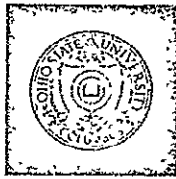
Research Acarologist
(winter quarter - 1/2 time) \$1,800

8. REFERENCES

Thompson, D'arcy W., 1942, GROWTH AND FORM; Volume 1; University Press, Cambridge, p. 464.

APPENDIX B

Materials Sent to Faculty Members for
Solicitation of Research Prospectuses



THE OHIO STATE UNIVERSITY

October 15, 1975

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TO: University Faculty in the Physical and Life
Sciences and Engineering

FROM: F. A. Kulacki and R. M. Nerem

SUBJECT: Announcement of University Small Grants Competition for
Development of Proposals to Perform Research Using the
Space Environment; Call for Research Prospectuses.
(Deadline: December 1, 1975)

The University has received funds from the National Aeronautics and Space Administration (NASA) for the purpose of identification of scientific programs and development of preliminary research proposals for utilization of the space environment.

Scientific experiments selected by NASA will be flown into earth orbit by the Space Shuttle Transportation System (STS) and orbited for an extended period on the Long Duration Exposure Facility (LDEF). LDEF will accommodate unmanned, passive experiments. It will be recovered in space by STS and flown back to earth where experimental data can be analyzed. A brochure describing STS and LDEF is attached.

The major objectives of the OSU development program are the following:

1. To encourage as large a number of University faculty as possible to consider the potential for contributions in their fields by conducting long duration experiments in space.
2. To provide an effective mechanism for research proposal development such that well-defined research plans can be submitted to the LDEF program.
3. To encourage as large a number of University faculty in as wide a range of disciplines as possible to examine societal and scientific benefits of LDEF.

These objectives are to be achieved through a University-wide solicitation of research prospectuses and the award of several small grants for development of some of the prospectuses

October 15, 1975
Page Two

into preliminary detailed research proposals for submission to NASA. Research prospectuses will be reviewed and evaluated on a competitive basis for the award of a small development grant.

All prospectuses submitted to the OSU program will be communicated to NASA so that University faculty will obtain maximum exposure for their ideas.

This announcement marks the beginning of the second round of prospectus solicitation.

Research Prospectus Review and Evaluation

Research prospectuses will be reviewed and judged suitable for further development by the following criteria:

1. The proposed research topic has sufficient specificity so that an experimental design with well-defined objectives can be developed.
2. The proposed research topic possesses the potential for making a significant contribution to scientific knowledge.
3. The proposed research topic and experimental approach have a high probability of success if implemented for LDEF.

The research prospectus shall follow a short two-page format; a prospectus form is attached to this communication.

The OSU project investigators and other University faculty with expertise in appropriate scientific and technical areas will review the prospectuses and make recommendations for the awarding of small grants.

Second round research prospectuses are due on December 1, 1975.

Small Grants Awards for Preliminary Proposal Development

A faculty member whose research topic has been selected for development of a preliminary proposal will be awarded a grant with a budget ranging from \$2000-\$5000. This grant will cover a portion of the faculty member's salary for one quarter and/or a stipend to a graduate student for one to two quarters so that proposal development can be done as part of the normal work load.

It is expected that from two to four grants will be awarded.

October 15, 1975
Page Three

The research proposals developed in this phase of the program for NASA will follow their specified 10-page format and will contain sufficient detail so that a decision for further funding can be made by NASA. If a research idea is selected for LDEF, funds will be awarded by NASA for further development of the proposed program.

Second round small grants will be awarded for Winter Quarter 1976.

FAK/adb

Attachments

C. 3

RESEARCH PROSPECTUS
for the
NASA Long Duration Exposure Facility (LDEF) Program

Instructions:

1. Please be specific but use additional sheets if necessary.

2. Return your prospectus by December 1, 1975 to:

Professor F. A. Kulacki
Department of Mechanical Engineering
206 West 18th Avenue
Campus

3. For additional information, please call Professor Kulacki (2-6676) or Professor Nerem (2-9524).

A brochure describing the LDEF in some detail is attached.

1. TITLE: _____

2 NAME: _____ CAMPUS PHONE: _____

CAMPUS ADDRESS: _____

3. RESEARCH OBJECTIVES:

4. JUSTIFICATION:

5. GENERAL DESCRIPTION:

a) Experimental Plan-

b) Experimental Apparatus-

c) Special or Unusual Design Requirements-

6. WHAT NEEDS TO BE DONE TO FURTHER DEVELOP YOUR RESEARCH IDEA INTO A MORE DETAILED PRELIMINARY PROPOSAL?

7. FUNDING REQUIREMENTS TO DEVELOP A MORE DETAILED PROPOSAL:
(Please include salaries and wages and other miscellaneous expenses):

THE SPACE SHUTTLE TRANSPORTATION SYSTEM (STS) AND THE LONG DURATION EXPOSURE FACILITY (LDEF)

Introduction

The Space Transportation System (STS) and the Long Duration Exposure Facility (LDEF) are described here to aid university faculty in proposing experimental research programs for LDEF.

In 1979, the Space Shuttle will begin making trips to and from space. This vehicle will signal a new era of space activities. It will provide more flight opportunities, carry larger payloads, and will be capable of retrieval of objects in space for return to earth. This expansion in capabilities makes possible a large expansion of the community of people who participate in space activities.

The Shuttle in combination with associated ground, payload, and orbital capabilities comprises the Space Transportation System (STS). Additional descriptive information on STS is contained in the article "The Reusable Space Transport" by Wernher von Braun, Amer. Scientist, 60, 730-738 (1972).

The Space Shuttle

The Space Shuttle is a transportation system designed to meet all of the needs for space activities in the 1980's and beyond at a fraction of the cost of present systems. The primary vehicle of the Space Shuttle System is the Shuttle Orbiter. This 126-foot long delta-wing manned spacecraft has maneuvering capabilities for orbit changes, return to earth, and landing on an airstrip. It is about the size of a DC-9 airplane. The Orbiter is boosted into orbit by two reusable solid-propellant rockets and its main liquid-hydrogen, liquid-oxygen engines that are fueled from a large expendable tank.

The Orbiter carries a normal crew of four in the cockpit and can lift a 29,500 kilogram (64,000 lb) payload to a 280-kilometer (150-mile

circular orbit or a 10,000-kilogram (22,000-lb) payload to 1100-kilometer (600-mile) orbit. The cargo bay can accommodate a cylindrical payload that is 4-1/2 meters (15 feet) in diameter and 18 meters (60 feet) long. A Remote Manipulation System will be available for transfer of payloads to and from the cargo bay.

The importance of the Shuttle derives from (1) its ability to transport a variety of useful spacecraft to orbit, (2) the lowering of costs and complexity of space operation, (3) its being a practical extension of manned space operations, and (4) the large increase in opportunities for participation in space activities that it makes possible.

Planned operating modes of Shuttle illustrate its versatility. First, Shuttle will accommodate short duration orbital missions during which activities will be carried out in the cargo bay. Depending on payload weight and orbit inclination, operations of 7 to 30 days at altitudes up to 1000 kilometers are possible. The Space Laboratory (Spacelab) and experiment pallets are being designed to accommodate both manned and unmanned payload operations in this mode. These operations will use the life support and instrumentation facilities of the Orbiter to support cargo bay hardware.

Long duration orbital activities will be carried out on unmanned satellites. Dedicated satellites will be delivered to orbit by the Shuttle and can later be retrieved. Earth resources and communication missions as well as the Large Space Telescope (LST) are examples of dedicated satellites. In addition, a large general purpose satellite, the Long Duration Exposure Facility (FDEF), is being designed to accommodate a variety of orbital activities which cannot justify or do not require dedicated vehicles. FDEF is retrieval and reusable.

Shuttle will also deliver propulsion stages which will provide orbital changing and deep space mission capabilities. The Interim Upper Stage, for example, is planned to boost Shuttle payloads into highly elliptical or geosynchronous orbits.

These operational modes will be supplemented by additional modes as the Shuttle comes into operation and additional payload experiments are defined. In one Shuttle traffic model for the period 1980-1991, 649

flights were scheduled. These will extend the versatility of Shuttle to its fullest capabilities and provide a full spectrum of opportunities to perspective users. However, at present, attention will be focused on LDEF and Spacelab which are currently being planned and which will carry most of the experiments for the early years of the Shuttle.

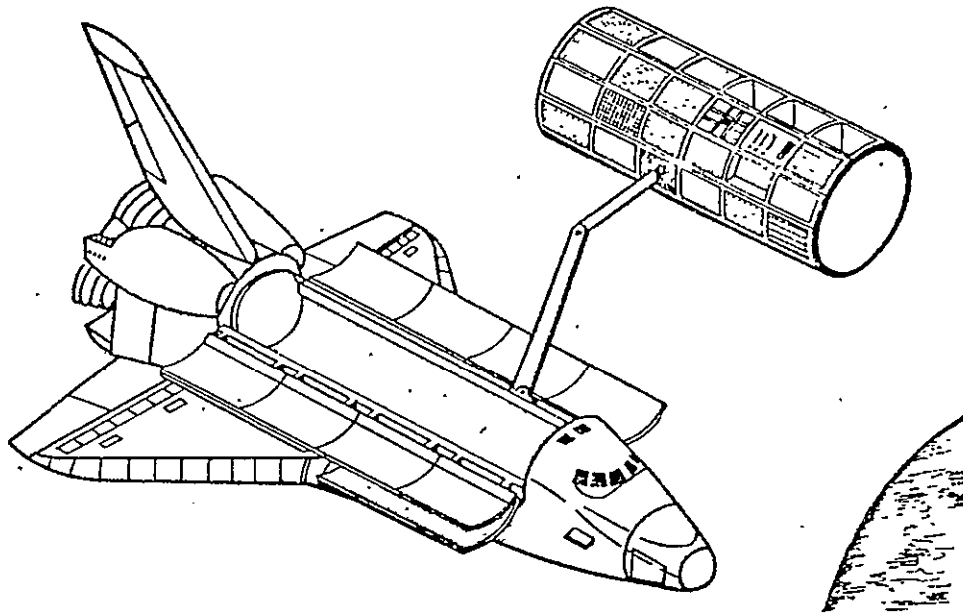
Long Duration Exposure Facility (LDEF)

The Long Duration Exposure Facility (LDEF) is a large unmanned space vehicle that will operate for an extended period in earth orbit. At the end of its mission, LDEF will be recovered from orbit by the Space Shuttle. It thus provides a unique opportunity for exposure of many different things to the space environment with subsequent analysis of the results in laboratories. Materials, components, systems, processes, and simple biological forms will be included among the LDEF experiments as will experiments to observe micrometeoroids, space debris, high atomic weight ions, and the Shuttle induced environment. The size of LDEF will allow opportunity for many experiments, thus the cost associated with each experiment will be small. Individual experiments will be in independent modular units for mounting on LDEF. These experiments will be less constrained by limits on weight or volume or by reliability requirements than most previous space activities. LDEF thus provides an early opportunity for important returns from the U.S. investment in the Space Shuttle.

Goals

The goals of LDEF are several but the most important is to bring the space environment within the reach of the large community of potential users. Where there is a recognizable benefit to be obtained from use of LDEF, it is intended that flight opportunities will be made available to the experimenters.

Specific goals for the first LDEF flight include the demonstration of its utility as an orbiting research vehicle for a variety of experiments, the definition of the near earth meteoroid and space debris environment, and the determination of the effect of Shuttle on experiments situated in its bay or in its vicinity.



Configuration

LDEF is a cylindrical frame approximately 4.4 meters (14.4 feet) in diameter and 9.1 meters (30 feet) in length. Its surface is partitioned into 72 bays by spaced ring frames and longerons. Each bay can accommodate a tray that is 1.2 x 1.4 m (4 x 5 ft) in area and can, if required by its experiment, extend through the diameter of the spacecraft. Most trays are expected to vary in depth from 10 to 100 cm.

Flight Plan

The first LDEF will be carried into a circular orbit of 500 kilometers (270 miles) in the bay of the Space Shuttle. Launched in 1980 from Kennedy Space Flight Center, the orbital inclination will be 28.5 degrees.

In orbit, LDEF will be removed from the cargo bay and released. The attitude of the cylindrical spacecraft will be gravity gradient stabilized so that its axis will point toward the center of the earth. Spin will be minimized by means of a magnetic damper. Temperature of the spacecraft will be passively controlled to approximately 293 ± 20 K ($68 \pm 36^\circ\text{F}$). The total weight will be about 4500 kg (10,000 lb).

This first flight is to occur as part of the Shuttle test series. Emphasis for this flight is being placed on low cost experiments that take advantage of the retrieval and that require no telemetry, control, or centralized electrical power source. Power sources and programmers may be provided that are integral with the individual experiments.

LDEF will remain in orbit for six months after which it will be retrieved from orbit and returned to earth. Individual experiment modules will be removed from the spacecraft and sent to each investigator for analysis.

LDEF spacecraft is reusable and a series of flights are planned. On subsequent flights, the flight plan may be considerably altered as required by the experiment payload. Spacecraft facilities such as power, data storage, and telemetry will become available. Within the capabilities of Shuttle, LDEF is designed to offer maximum versatility for unmanned orbital activities.

Space Experimentation

Activities in orbital space generally fall into one of the following categories:

- Determining and using the unique behavior of biological, chemical, or physical systems in the absence of gravitational forces.

- Determining the behavior of materials and systems in the combined low gravity, vacuum, and radiation conditions of orbital space and investigation of applications of this behavior.

- Observation of terrestrial objects and phenomena (meteorology, geology, vegetation, oceanography, earth resources).

- Determining the nature of the space environment (matter, radiation, forces).

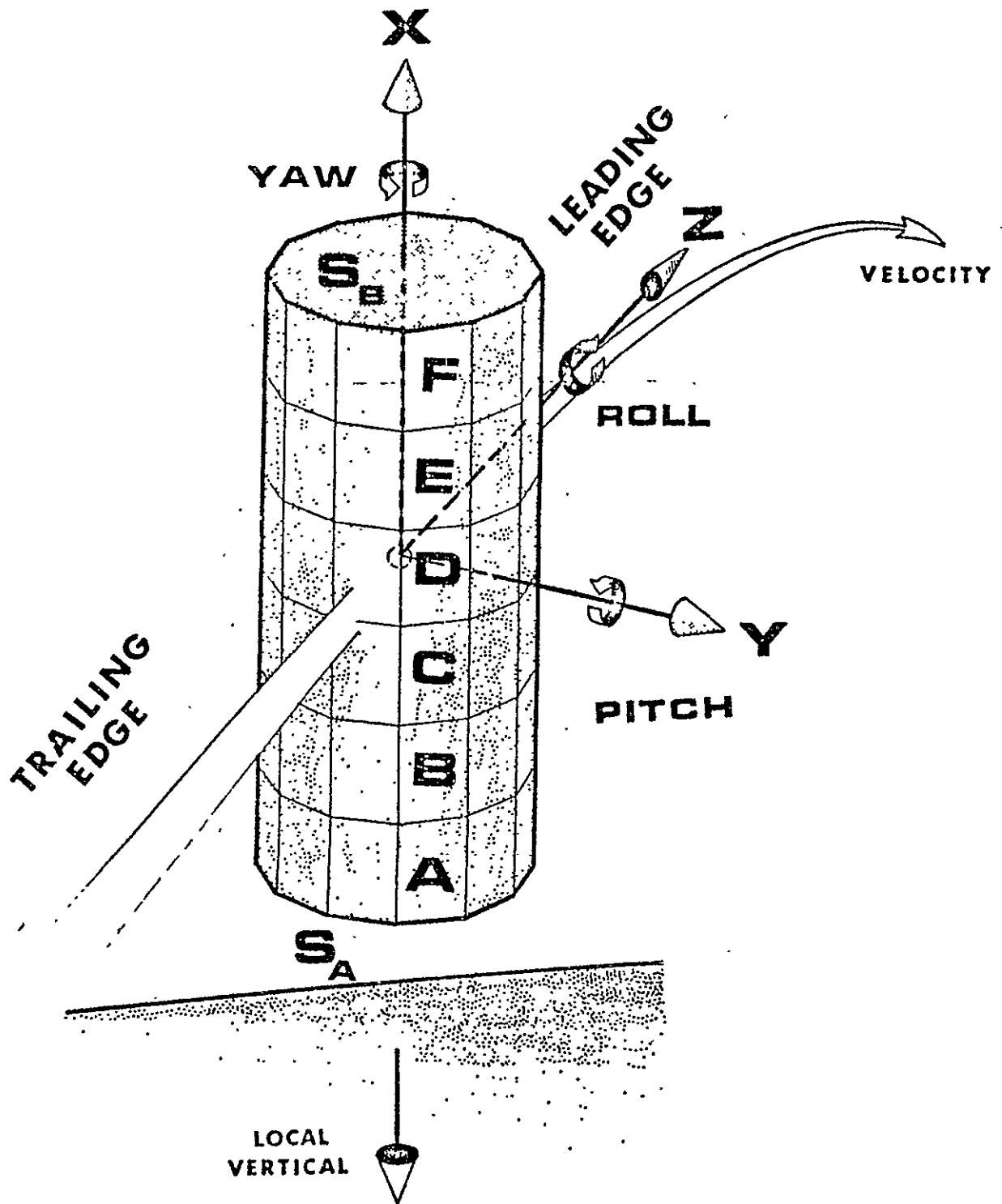
- Observations of extraterrestrial objects and phenomena (solar; lunar, stellar, planetary, and galactic; flares, solar winds, etc.).

- Engineering studies of components, structures, and systems for space applications.

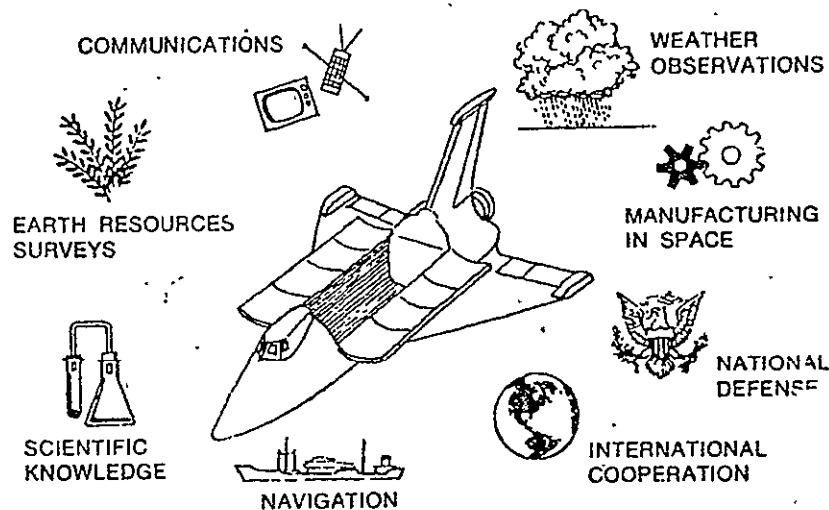
- Studies of man's capabilities for carrying out useful functions in space.

- Developing and deploying satellites for communications, navigation, and beacon location.

Sustained low gravity conditions are obtainable only in space. On earth, gravitational forces affect many phenomena. For macroscopic



systems involving solid masses, the effects are usually apparent. For fluid, multiphase, or dispersed systems, the effects are not readily predictable. Experiments in the growth of crystals, solidification, solid-liquid interfacial phenomena, polymerization, and biological cell growth have been discussed and some preliminary experiments were carried out on Skylab. Each of these subject areas



has the potential for much expansion, and creative researchers can define additional areas for which experimentation in the absence of gravity will provide valuable knowledge and applications.

In space, the uniqueness of the environment is not limited to the absence of gravity. The absence of appreciable atmosphere not only provides a vacuum but also a much altered energy environment. Vacuum is attainable with relative ease on earth but is characterized by 1) residual chemical species derived from the hardware involved, 2) limited working volume, and 3) restrictive geometries. These restrictions are altered in space to allow different types of vacuum experiments.

The absence of the atmospheric attenuation of radiation is equally significant. Solar radiation is altered in its spectral intensity by the atmosphere. In orbit, both the long and short wavelengths of the solar spectrum are more intense. In addition, the total solar intensity is about 30 percent higher in space due to the absence of atmospheric attenuation. The value of the solar constant is approxi-

mately 1350 Wm^{-2} under these conditions. Cosmic radiation, consisting of energetic charged atomic nuclei, also exists with unattenuated intensity in space.

The applications of observational platforms in orbit are well advanced. Image sensors sensitive in various spectra regions are finding applications in meteorology, geology, agriculture, oceanography, and astronomy. Active radar and lidar systems for observing terrestrial phenomena are being investigated. There remain many opportunities for fruitful use of orbital observation platforms in monitoring and examining natural and cultural features and phenomena on the earth and in outer space.

Some of the specific activities planned for LDEF and Spacelab are listed below. Certain experiments are logically performed on a specific vehicle, others may be carried out on either.

Space Testing

Extensive simulation has been required in the past to space qualify a variety of materials, assemblies, and systems. LDEF and Spacelab provide means for carrying out such tests that are cost competitive and that allow testing in space instead of in simulation facilities with a consequent increase of confidence in the test results.

Space Characterization

While knowledge of the space environment has expanded rapidly the last fifteen years, there are still unknowns for which LDEF and Spacelab measurements will be valuable. This is illustrated by measurements of meteoroids and space debris and of high atomic weight cosmic particles that require large area detectors such as will be possible on LDEF. Large masses are required in order to ascertain the level of gamma ray emission that results from neutron activation in orbit. The characterization of space in the immediate vicinity of Shuttle is crucial to many activities.

Space Processing

Space operations that provide enhanced value to materials or objects for later use on earth often benefit from human participation such as on Spacelab. Types of processing that may be more suited to LDEF include the reaction of hazardous materials and operations that require extended periods

low gravity. The absence of gravity opens new vistas for applied research on materials and orbital manufacturing operations. For example, ultrapure metals, semiconductors, and glass may be produced by processing free of contact with containers for research use and applications in such areas as electronics, laser technology, and optical products. Greatly improved crystals may be produced for computers, communications, and other electronic uses. New types of composite materials with increased strength at high temperatures may be produced, and new knowledge about materials may be acquired to advance processes used on the ground.

Observations

There will be many dedicated observation platforms such as ERTS, ITDS, and LST which provide sophisticated capabilities for looking at either the earth or objects in space. However, while certain types of measurements such as long term integrated energy flux for heat balance studies may be carried out on LDEF or Spacelab, their primary mission will be to test instruments and sensors that will later fly on the dedicated satellites. Spacelab will also offer the ability to respond rapidly with simpler instrumentation to observational opportunities as they appear — either astronomical events or terrestrial phenomena.

Biological Sciences

The effects of and applications of the space environment in the biological sciences have provided a basis for much speculation as to what may or may not be possible. The extremely stable, gravity-free environment of a space platform should be ideal for several types of highly delicate separation methods used to isolate specific biological materials. Such methods may be used to obtain preparations of particular types of cells of high purity for transplantation, to prepare concentrated antibodies for treatment of specific diseases, or to purify materials such as vaccines to eliminate contaminants that can cause undesirable side effects. These techniques will be developed on a small scale initially to support medical research, but if materials identified in such research are needed for large-scale use, they might be processed in space.

Space flights to date, but isolating the effects of gravity, have indicated interesting changes in man and suggested that there are metabolic

and associated changes in plants and animals. Repetitive studies of these phenomena will add to knowledge of medicine and contribute to the advancement of understanding of fundamental mechanisms in life processes.

Physical Sciences

Gravity effects on physical systems are found, for example, in the study of liquids at their critical points, reactions in heterogeneous systems, liquid-solid interfaces, and crystalline growth and imperfections. LDEF experiments will not only lead to a better understanding of these systems but may also enable the attainment of altered systems, e.g., super high molecular weight polymers, larger varieties of compound crystals, or more perfect crystals.